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# STUDENTS' METACOGNITIVE SELF-REGULATION – A CASE STUDY: MOLECULAR STRUCTURE PROBLEM SOLVING

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**Abstract.** The purpose of this study was to determine the students' metacognitive self-regulation in problem solving of molecular structure based on the rank of students in the upper, middle, and lower groups. This research type was exploratory by using qualitative approaches. In the study participated students who followed the school course on chemical bonds. The methodology included document analysis technics and deep interviews. Additionally triangulation technics of sources and methods were used to check the credibility of the data. The results showed that: (1) planning dimensions not only performed on the problem analysis and plan phases, but also performed on the problem solving phase. Planning activities on the problem solving phase just carried out by the upper and middle groups because these groups were more careful and thorough in considering and planning the use of prior knowledge to solve problems; (2) monitoring dimensions carried out by all group in problem-solving phase, but the upper group used their knowledge more, more carefully, and more in detail than subjects in the middle and lower group, and (3) reflection dimensions carried out by the upper and middle groups in the evaluation phase, and no reflection by lower group.

*Keywords*: metacognitive self-regulation, problem solving, molecular structure

## Introduction

Molecular structure is among of the chemical concepts which are abstract and difficult for understanding by students. Something that were often encountered in this study included: (1) when asked to define the molecular structure, it turned out the students had difficulty in determining the central atom and the type of single or double bonds; (2) students also had difficulty in describing the molecular structure of dimers compounds, like $Al_2Br_6$ and $B_2Cl_6$; and (3) students could not determine the molecular structure consisting of two, three, or four central atoms, such as ethane, propane, butane, or other organic molecules. In addition, the students also had difficulty in determining the bond angles of a molecule in three dimensions. Students seemed to have less sharp in analyzing the given problem. The students' in comprehension or mistake not only caused fatal in occupied course, but also in other subjects. In this study, the definition of problem

solving was phases taken by students in giving answer to a problem according to the phases: problem analysis, planning, problem solving, and evaluation.

The impact of students' less sharpness in solving the above problems was not only caused by the learning process activities that took place in classroom, but it was suspected that there were other causes within students. Tobias & Everson (2002) found that the ability of learners to distinguish between what was known (or what they had learned) and unknown (or unlearned) was an important thing for reaching success in all academic settings. Schunk & Zimmerman (1994) found that learners with high metacognitive ability knew whether they had completed or not in mastering academic tasks and able to customize their learning. This study examined the metacognitive self-regulation of students in solving chemistry problems that were abstract, especially molecular structure which were one subjects in the course of chemical bond.

One of the important issues in learning self-regulation was the ability of learners to select, combine, and determine the strategy in an effective way. According to Panaoura & Philippou (2003), self-regulation strategies played an important role in learning process. Successful learners were able to quickly transfer knowledge and strategies gained from a situation to a new situation, modify, and extend the strategy in practice. Ability to perform self-regulation was also known as the ability to control or regulation of cognition process. In this study, metacognitive self-regulation arrangement also called cognition was intended to be the most dominant of the students' activities in using metacognitive self-regulation strategically to achieve goals. On its application in solving the molecular structure problems, the metacognitive self-regulation included planning, monitoring, and reflection dimensions (Cohors-Fresenborg & Kaune, 2007 and Pulmones, 2007). In metacognition process, all of the three components were one in a series of interconnected metacognition activities. This regulation capability was needed in solving the problem or task. Planning was connected to the selection of strategies and allocation of resources. Monitoring describes a person's ability to follow the self-understanding and/or uptake of both assignments. While reflection was with respect to the ability to critically assess the process and outcomes of their own learning.

The results of some study claimed that higher-achieving students were more accurate in predicting the results of their tests, more realistic in setting goals, and better at adjusting their confidence. In addition, students with higher achievement were more effective in selecting an answerable problem. This study supported the relationship of metacognitive knowledge monitoring (MKM) on self-regulated learning and academic success (Isaacson & Fajita, 2006). Moreover, research showed that there was no significant difference between metacognitive awareness of male and female learners. The results also performed a vital role between metacognition primarily to academic achievement, that learners with high metacognitive awareness obtain better test results

than learners who have low metacognitive awareness (Rahman etal., 2010). Having regard to some previous research results, this research paid attention to the cognitive abilities of students who were distinguished by rank (GPA, grade point average) into the upper, middle, and lower groups.

Based on the above description, this study aimed to describe the flow of student metacognitive self-regulation in the upper, middle, and lower groups in problem solving of molecular structure corresponding phases of problem analysis, planning, problem solving, and evaluation. From the above research objectives, the focus of this study was to obtain information about the flow of student metacognitive self-regulation of upper, middle and lower groups in terms of planning, monitoring, and reflection dimensions in problem solving of molecular structure.

**Method**

This study would reveal students reasoning in solving problems of molecular structure. This study was a qualitative research, because it was done in a natural setting or in context of an entity. The thought profile was studied using the framework of metacognitive self-regulation activities according Cohors-Fresenborg & Kaune (2007), which consists of planning, monitoring, and reflection dimensions.

As research subjects were students of the Department of Chemistry, State University of Malang, Indonesia who programmed the Chemical Bonding courses in semester 3. In this study the subjects were two students from each group, namely: a) the two subjects of the upper group of students who earned a GPA of $\geq 3.00$, b) two subjects of the middle group of students who earned a GPA of 2.75-2.99, and c) two subjects of the lower group of students who earned a GPA of 2.50 to 2.74.

The main instrument in this study was the researcher as human instrument supported by tools such as audio recorders, camcorders, and field notebook. This study used data triangulation which aimed to test the credibility in data. This research used triangulation of methods and sources. Triangulation method is done by comparing the information or data in a different way, i.e. using interviews and observation documents (an answer written by the subject) to check the truth. Triangulation of data sources used to dig the information through a variety of methods and sources of data acquisition. This research used written documents and interviews (Lincoln and Guba, 1985).

To know the dimensions of subjects' metacognitive self-regulation activities in solving the molecular structure problem, this research used guidelines as a basis for analyzing the problem solving according to the research focus. This study used the Guidelines on the Identification Problem Solving Phases (Utomo and Ruijter, 1985) which were shown in Table 1. To identify the metacognitive self-regulation activities, the researcher used Dimensional Activity Guidelines of Identification Metacognitive Self-Regulation by Co-

hors-Fresenborg & Kaune (2007) and Pulmones (2007) which were modified according to the research needs for solving the molecular structure (Table 2).

**Table 1.** Problem solving phases

| Phase | Code |
|---|---|
| Analysis of The Problem | PS-1 |
| Plan | PS-2 |
| Problem Solving | PS-3 |
| Evaluation | PS-4 |

**Table 2.** Guidelines of identification metacognitive self-regulation

| **Dimensional Activities of Metacognitive Self-Regulation** | | | | | |
|---|---|---|---|---|---|
| **Planning** | | **Monitoring** | | **Reflection** | |
| P-1 | Thinking/reading/ writing what one knows and does not know | M-1 | Repeatedly reading a material until one can understand | R-1 | Reflecting on the concepts/objectives have been achieved |
| P2 | Determining goals | M-2 | Using rules, such as: molecular formula/structure, equation. diagrams, and graphs. | R-2 | Reflecting implementation/ application more efficient strategy |
| P-3 | Determining the problem-solving strategies | M-3 | Monitoring something that is considered an error such as writing, drawing, molecular formula/ structure, and others. | R-3 | Analyze of the text, molecular formula/ structure, and image. |
| P-4 | Determining intermediate results that can be achieved | M-4 | Monitoring carefully in problem solving | R-4 | Analyzing the way or structure of decision-making |
| P-5 | Planning a representation (molecular formula / structure, reaction equations, text, images) to support understanding | M-5 | Monitoring by arguing | R-5 | Choosing intentionally in the form of are presentation (molecular formula, structural formula, text, images) |
| | | M-6 | Reveals lack of understanding | R-6 | Recognizing the interaction between there presentation and the idea that one as a control theme. |
| | | M-7 | Monitor planning deficiencies | | |
| | | M-8 | Monitoring match between fact and purpose/goal | | |

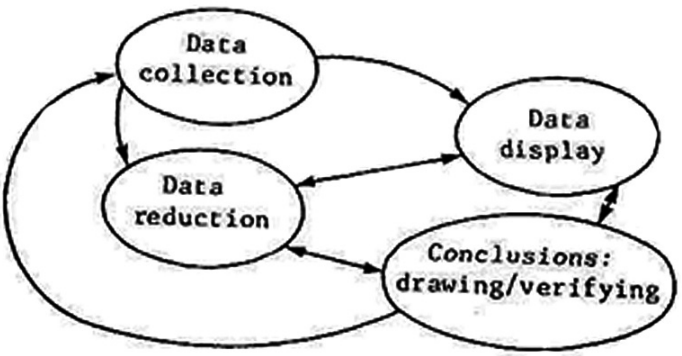


**Fig. 1.** Component of data analysis: interactive model

Qualitative data analysis used in this research followed the pattern of Miles and Huberman (1994), which divided into three processes: (1) data reduction; (2) data display; and (3) conclusion: drawing/verification shown in Fig. 1. In these three processes, all steps might not be sequential, but could occur at the same time and repeatedly. From the picture, it appeared that the data had been collected and examined; furthermore a data reduction had been conducted.

Data reduction process included: selecting, focusing, simplifying, abstracting, and changing the data to be written in a field notebook. Data reduction performed continuously throughout the execution of qualitative research. This data was then presented (data display) included: classification, compress the information, and identification to make it easier for drawing conclusions. The final step was making conclusions (drawing/verifying). This process went on during the study.

**Result**

Based on the analysis of the above data, the flow of metacognitive self-regulation done by groups of upper, middle, and lower in problem solving of molecular structure involved some scattered activities in the analysis (PS-1), planning (PS-2), and problem solving (PS-3) phases. Metacognitive self-regulation in the evaluation phase (PS-4) was only carried out by the subjects of upper and middle groups. Paying attention to the analysis flow, the flow profile for metacognitive self-regulation of students in molecular structure problem solving could be illustrated as shown in Table 3.

**Table 3.**Students' metacognitive self-regulation in problem solving of molecular structure

| No. | Problem Solving Phases | Metacognitive Self-Regulation Activities | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *Planning* | | | *Monitoring* | | | *Reflection* | | |
| | | U | M | L | U | M | L | U | M | L |
| 1. | Analysis of the problem (PS-1) | **P-1** | **P-1** | **P-1** | | | | | | |
| 2. | Plan (PS-2) | **P-3** | **P-3** | **P-3** | | | | | | |
| 3. | Problem Solving (PS-3) | **P-4** | | | **M-2 M-4 M-5** | **M-2 M-4 M-5** | **M-2 M-4 M-5** | | | |
| 4. | Evaluation (PS-4) | | | | | | | **R-3** | **R-3** | |

*Note: U – Upper group; M – Middle group; L – Lower group*

Metacognitive self-regulatory dimensions of planning in problem analysis phase (PS-1), which conducted by all groups in terms of *thinking/reading/writing what was known about the problem* (P-1). Activities carried out on an upper group of subjects were reading then writing about problems, coordination number (CN), bond pair (BP), and lone pair (LP) of central atom. Activity in the subjects of middle group was writing $XeO_3F_2$ molecular formula and the central atom; meanwhile activities undertaken by the lower group were as same as the upper group. In the planning phase (PS-2), three groups held activities of self-regulatory metacognitive *determining the problem-solving strategies* (P-3) to estimate the structure and size of the bond angle, which determining the central atom of a molecule and calculate CN, BP, and LP.

Activity in planning dimensional was *determining intermediate results that could be achieved* (P-4) on the phase of problem solving (PS-3) held by the upper and middle groups. The upper group wrote the Lewis electron structure of $XeO_3F_2$ to check the correctness of the valence electrons number per atom contained in the $XeO_3F_2$ molecular formula, while the middle group specified the type of bond that was $AX_5$ trigonal bipyramidal.

Metacognitive self-regulation activities monitoring dimensional was carried out by the three groups in problem solving phase (PS-3). Activities *using rules* (M-2) performed well by the upper, middle, or lower groups. There was little distinction made by the three groups. Activities undertaken on the subjects of upper group were using CN, BP, LP, and Bent's rule in determining the molecular structure, the location of substituent atoms

and the amount of the bond angle. The middle group of subjects used CN, BP, LP, and the results of the $AX_5$ bond type for determining the molecular structure, the location of substituent atoms and the amount of the bond angle, while the lower group only used information of CN, BP, and LP.

The three groups also *monitored carefully in problem solving* (M-4). In this case, the upper group paid attention to the nature of polarity, electronegativity, Bent's rule, hybrid orbital, and the role of oxygen and fluorine atoms on counting CN of $Xe0_3F_2$ molecule, while the subject of middle and lower groups did the molecular structure drawing and determining the bond angles.

Other activities on the monitoring dimension conducted by the upper, middle, and lower groups in the problem-solving phase (PS-3) was doing *monitoring by arguing* (M-5) on the determination of the bond angles amount and position of substituent atoms depended on the electronegativity of atoms.

Self-regulatory metacognition only held by upper and middle groups in the evaluation phase (PS-4) in terms of analyzing the way of decision-making the $XeO_3F_2$ molecular structure (R-3). The analysis conducted by the upper group associated with the presence of a double bond between the Xe=O so that formal charges became zero because the formal charges also affected the structure and size of the bond angle, while the analysis done by the middle group just mentioned that the amount of bond angle at O=Xe=O was the same and the molecule constituted a double bond. In the assessment phase (PS-4) the lower group did not perform activities of metacognitive self-regulation reflection dimension.

**Discussion**

In this section we discussed some of the findings about the metacognitive self-regulation of upper, middle and lower groups in solving problem the molecular structure based on: analysis phase (PS-1), planning (PS-2), problem solving (PS-3), and evaluation (PS-4), as well as its association with the theories, research results, and the opinion of several experts.

*Metacognitive self-regulation of planning dimension*

Planning dimension was regulatory skills which occurred before learning or problem solving activities done before. This was kind of preparation to decide the components required in setting learning goals. This increasing skill could lead to increase awareness about what to do to improve academic performance (Şendurur et al., 2011).

At the phase of analyzing problem (PS-1) the three groups of subjects used the same self-regulatory activity for P-1 type, which was the subject of settlement began to read and then write the molecular formula of $XeO_3F_2$, continued to determine CN, BP, and

LP of central atom. At this phase the subjects accurately identified and understood the problem. Subjects had to check and interpret the problem correctly according to their knowledge and experience.

The above activity supported the idea from Gok (2010), that subjects should decide what important information was on the problem and what information was required in the first step. It was also in accordance with the opinion of Schoenfeld (Rysz, 2004), which stated when a person read a problem, he could feel indirectly that he understood or did not understood what he read. Here the aspect of metacognition related to individual knowledge was needed and through this stage people who resolved the evaluation would arrive in what he thought was also one aspect of metacognition experience.

According to Bereiter and Scardamalia, as well as Gordon and Perry (Hammann, 2005), by doing writing meant the subject determined his attitude to plan what would be done, including the content/materials used as well as the source of knowledge. By writing questions/problems, meant the subject knew what was known and what was unknown. Ann Brown (Hackeret al., 2009) argued that a person who knew what was known and what was unknown was categorized into the cognition of the understanding of self-knowledge (self-understanding). Polya (1973) said that the things which existed in problem solving, i.e. what was unknown, what data was available, what its terms, and so on were included in the stage of understanding the problem. Activities carried out by three groups according to Pulmones (2007) included metacognition activities for the planning dimensions in problem solving, might be in terms of thinking and writing what was known and what was unknown, as well as identifying where the place to find information that had not known yet.

All of group subjects in the planning phase (PS-2) used a similar self-regulatory activity work flow, namely the determination of problem-solving strategies (P-3). In this case the all of groups subject determined the central atom of a molecule and calculated CN, BP, and LP to predict the structure and size of the bond angle. This meant that determination CN, BP, and LP was the beginning of knowledge that could help them to solve problems. At this phase the subjects knew what to do first.

When determining the central atom, subjects connected it to some rules. According to Effendy (2010) the rules in determining the central atom of a molecule were: (1) the central atom was usually written at the beginning of the molecular formula; (2) had a lower electronegativity or more electropositive than the substituents atoms; (3) the size of central atom is larger than the substituents atoms; and (3) for a molecule or polyatomic ion that had a varies central atom, usually the central atoms written first in the formula. Determination of Xe as the central atom, and CN, BP, and LP by the subjects of upper group were in accordance with the provisions of the VSEPR theory, namely the atoms that had the greatest size compared to substituent atoms. In calcu-

lating CN, subjects used the terms set forth in the following equation: CN=½(valence electron of central atom + number of electrons donated by the substituent - existing charge) (Effendy, 2010).

At the $XeO_3F_2$ molecule, its CN was 5 (five) which was obtained from two BP sigma (σ) between the Xe central atom with two F substituent atoms and three BP sigma (σ) between the Xe central atom with three O substituent atoms, whereas BP bonding pair phi (π) between the central atom Xe and O atoms were not included in the determination of the CN of the central atom, because the bonding phi (π) did not affect the determination of molecular structure. In the $XeO_3F_2$ molecule there was no LP that affected the calculation of CN.

Woolfolk (1998) argued, that the selection strategies (P-3) of what to use, what resources needed to be collected, how to begin, and which should be followed or implemented first were included in the metacognitive skills of planning in problem solving. According to Polya (1973), the determining of problem-solving strategies (P-3) aimed to find a relationship between one problem and another or the relationship between the data and the unknown thing, and so on. This opinion was in accordance with the view of Jacob and Paris (Jbeili, 2003), that the components of cognition planning arrangements included setting goal, activating the relevant resources, and selecting the appropriate strategy, while according to Flavell (Desoete, 2001) the activity was categorized as strategic variable of metacognitive knowledge, namely knowledge about how to do things, how to overcome the difficulties that arouse, or how to achieve the target.

Activity to determine the problem-solving strategies was undertaken by the all of group subjects. According to Schraw et al. (1995), it was an activity in taking the necessary steps for learning to use cognitive strategies. Schraw's opinion, which was reinforced by Sandi-Ureña (2008), stated that the activity in a problem solving planning stage could be allocation of resources and strategy selection. Previous research had shown the existence of appropriate information, in which the subjects had to simplify the problem by describing the situation using a simple diagram or sketch of objects and expressing what they wanted to be found mathematically for certain quantity (Gok, 2010).

At phase of problem solving (PS-3), the upper and middle groups used P-4 type that was determining intermediate results that could be achieved. There was a material difference between the set as a result by the upper and middle groups. Subjects in the upper group used Lewis electron structure (or electron dot formula) to check the correctness of the number of valence electrons per atom contained in the molecular formula for $XeO_3F_2$, meanwhile the subjects of the middle group used the type of bond $AX_5$ to determine molecular structure $XeO_3F_2$. This showed that the upper and middle groups were being more carefully and thoroughly in considering and planning the usage of initial knowledge to solve problem.

The determination of 'between results' done by the upper group was characterized by describing the Lewis structure (or electron dot formula) for $XeO_3F_2$ molecule as shown in Fig.2. This figure was made by the subjects of upper group to check the correctness of the number of valence electrons per central atom. The Lewis symbol is a symbol of an atom surrounded by dots that stating the valence electron of an atom, while the Lewis structure could be defined as a combination of a Lewis symbol from atoms stating molecules or ions polyatomic (Effendy, 2010).

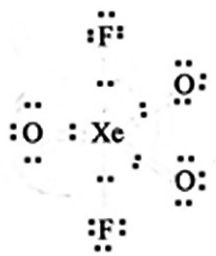


**Fig. 2.** Lewis structure of$XeO_3F_2$

Activity in the dimensions of planning was involving the identification and selection of strategies and the corresponding resource allocations, also including setting goal, activating background knowledge, and constructing time (Schraw et al., 2006). In planning dimension, the subjects found that the learned material could be applied to solve problem. Therefore it could be said that subjects were able to use their initial knowledge to construct something new. The activity showed strong evidence that the subjects had studied beyond their already gained content knowledge. This indicated that subjects had done the manifestation of meaningful learning. According to Slavin (2009), meaningful learning was mental processing that relating new information to information or concepts that had been previously owned by learners. Statements contained in the theory of constructivism were in accordance with the "meaningful learning" of Ausubel (1968) which learners attempted to connect new knowledge (whether it was factor concept) with relevant concepts that were owned or had been around in one's cognitive structure.

The important thing obtained in this study was "self-regulatory metacognitive dimension of planning that was performed by the subjects in the upper and middle groups not only at the stage of problem analyzing (PS-1) and planning (PS-2), but also performed at the stage of completion matter (PS-3). This finding was also consistent with the results of previous studies, that students who gained better achievement were more accurate in predicting their tests results, more realistic in their goals, more likely and better at

adjusting their confidence in line in accordance with the test results, and also they did more effectively in problem solving (Isaacson & Fajita, 2006). Coutinho (2007) in his research obtained findings, that there was a relationship between metacognition with academic success, i.e. learners who had good metacognition proved to have a high GPA.

*Metacognitive self-regulation of monitoring dimension*

Monitoring was carried out during the activities in the phase of problem solving (PS-3). This might be regarded as a self-evaluation or self-feedback during the learning process. If learners improved self-evaluation, awareness of the learning performance might become more apparent after each problem solving. Furthermore, academic success could be affected by the learners' awareness about what strategies should be done for the context or content (Şendurur et al., 2011).

Metacognitive self-regulatory activity monitoring dimension that conducted by the three groups of subjects at the phase of problem solving (PS-3) used the rules (M-2). This mentioned rules were using CN, BP, and LP to determine the structure, the location of substituent atoms (F and O atoms), and the amount of the bond angles in the molecule. In these cases, the upper group used Bent's rule to determine the structure, the location of the substituent atoms and the magnitude of the bond angle, while the middle group used the 'between result' of bond type for $AX_5$ to determine the structure, location of substituent atoms, and the magnitude of bond angle. This performed that the two groups were more digging existing knowledge deeply, and using rules to resolve the problem in more detail. At the stage of completion of this matter, subject called back information about the rules determining CN, BP, and LP that had been stored in long term memory, as well as other rules. Subjects felt the significance of information from prior knowledge to solve problems.

Self-regulatory metacognitive monitoring dimension at the problem solving phase (PS-3) was performed by the lower group as same as what carried out by the middle group, which using the information about the magnitude of CN, BP, and LP (M-2) to predict the molecular structure and bond angles $XeO_3F_2$. The middle and lower group used CN, BP, and LP to obtain trigonal bipyramide $XeO_3F_2$ molecular structure. In this phase of the problem-solving, metacognitive self-regulation activities were undertaken by the upper group in more detail. Subjects in the upper group not only used CN, BP, and LP to predict the structure and size of the bond angles in $XeO_3F_2$ molecule, but also used their knowledge about Bent's rule application in determining the location of substituent atoms. According to Effendy (2010) the forecasting of molecular structure could be carried out through four main steps, namely determining: (a) the central atom, (b) the CN of the central atom, (c) the number of BP, and LP on the central atom valence shell, and (d) the molecular structure along with the estimated size of the corners of the

existing bond. Manku (1980) stated that a molecule with CN = 5 had trigonal bipyramide molecular structure as shown in Fig.3. These upright position of Xe-F bonds were called axial bonds; Xe=O bond in horizontal position was called equatorial bond. F bond angle (axial)-Xe=O (equatorial) was 90°; F bond angles (axial)-Xe-F (axial) was 180°, and the O bond angle (equatorial) = Xe-O (equatorial) is 120°.

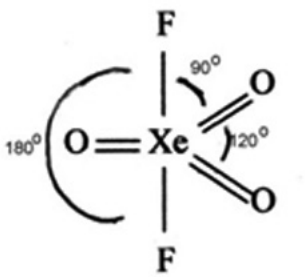


**Fig. 3.** Molecular structure of $XeO_3F_2$

Monitoring carefully in problem solving activities (M-4) performed by the subjects of upper, middle, and lower groups at the problem-solving phase (PS-3) were describing the arrow's direction on the determination of $90^o$, $120^o$, and $180^o$. The upper group of subjects also performed a careful monitoring such as: providing the bottom line on the answer, paying attention to the role of the substituent atoms for their contribution in calculating CN, linking electronegativity with Bent's rule in determining the location of substituent atoms, as well as the existence of hybrid orbital in a trigonal bipyramidal molecular structure. This indicated what had been made by the subjects of upper group was more accurate and more detailed than the other two groups.

At phase of problem-solving (PS-3) the subjects of upper group did monitoring carefully in problem solving (M-4) in resolving issues related to the role of oxygen atom and fluorine atom as the atoms that gave contribution or not to calculate CN of $Xe0_3F_2$. In addition, the upper group of subjects performed careful monitoring to determine the bond angle, which connecting with the polarity, electronegativity, Bent's rule, and hybrid orbital. According to Polya (1973), learners did checking activities in every single step of whether the measures taken were true, while according to Woolfolk (1998), monitoring activity was a direct awareness of how learners did a cognitive activity.

The subjects in the middle and lower groups in solving the problem (PS-3) also did careful monitoring (M-4) by drawing a complete molecular structure with bond angles. Subjects used CN, BP, and LP information to resolve problems that the molecular structure of $XeO_3F_2$ had the general formula $AX_5$ in trigonal bipyramidal. According to

Jacob and Paris (Jbeili, 2003) the inspection included monitoring one's progress and selecting appropriate remedial strategies as the previous strategies had not functioned well. This was consistent with research findings by Rickey & Stacy (2000) which saying that learners who applied metacognition activity monitoring and regulatory dimensions/ good thoughts settings could increase the success in resolving problem. According to Pulmones (2007) this activity was a manifestation of checking progress against goals or to-do list dimension. The subjects who did monitoring carefully meant that they use the memorized information as a learner's needs which requiring important information to keep in mind.

At phase of problem solving (PS-3) the all groups of subjects performed the same activities in monitoring by arguing (M-5) that the determination of the bond angle's magnitude and the position of substituent atoms depended on the electronegativity of atoms. O atoms which were larger in size or less electronegative would occupy the position of equatorial triangle with a larger angle (120$^{o}$), F atoms which were smaller or more electronegative would occupy axial position with a smaller angle (90°). Activities undertaken by the three groups of subjects were considered as monitoring efforts to explain problem and that the position of substituent atoms on trigonal bipyramidal molecular structure depended on their electronegativity.

This argument was supported by the Bent's rule of substitution on trigonal bipiramidal, i.e. the substituent trigonal bipyramidal with more electronegative preferred hybrid orbital with a smaller *s* character, whereas the more electropositive substituent preferred hybrid orbital with a larger *s* character. So, the more electronegative F atoms occupied lesser space (axial position), while the O atoms with more electropositive occupied more loosely one, namely the equatorial position (Effendy, 2010). Xe atoms in $XeO_3F_2$ molecule used five hybrid orbitals $sp^3d$ that's could be divided into two groups of hybrid orbitals, i.e. three $sp^2$ hybrid orbitals and two *pd* hybrid orbitals as shown in Fig.4. Two

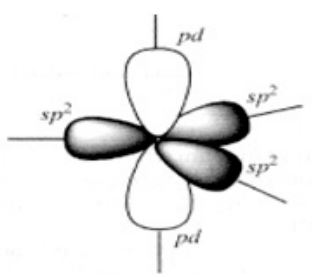


**Fig. 4.** Orbital Hybrid $sp^3d^2$ (two *pd* hybrid orbitals on the axial position and three $sp^2$ hybrid orbitals in equatorial position)

hybrid orbitals were on the opposite axial position; three $sp^2$ hybrid orbitals had their leading position on the corners of equilateral triangle. Two *pd* hybrid orbitals were used to form axial bonds, while three $sp^2$ hybrid orbitals were used to form the equatorial bonds. For the hybrid orbitals there was a provision that the rise of s character would increase its electronegativity. $Sp^2$ hybrid orbitals with s character of 33.33% were more electronegative than *pd* hybrid orbitals that did not have the s character.

Subjects' activities in the middle and lower groups as mentioned above were in accordance with one of the important steps in Polya (1973). It was said that the settlement of the problem was included of checking every step solution whether the measures taken were correct or could be proven that the moves had been taken correctly.

From the discussion of the above monitoring activity, it appeared that the three groups of subjects had done monitoring on the problem-solving phase. Subjects in the upper group used more knowledge and more details in monitoring than the subjects in the middle and lower groups. This showed that the subjects in the upper group understood better about the problems encountered, particularly on the dimension of metacognitive activity self-regulation using information, and monitored carefully the information in problem solving. In using the information, the subjects from the upper group predicted the structure and size of the bond angles of $XeO_3F_2$ using CN and BP. They also apply Bent's rules to determine the position of substituent atoms. The subjects of the upper group were also doing monitoring more carefully, due to consider whether the oxygen and fluorine atoms gave contribution or not in calculating CN for $Xe0_3F_2$. These subjects were also determining the bond angles more carefully, i.e. giving attention to polarity, electronegativity properties, Bent's rule, and hybrid orbitals.

Accuracy conducted by the subjects of upper group was in accordance with the opinion that learners should be actively involved in self-appraisals and the management of thinking. Learners monitored their own learning, learnt to check their answer and realized if there was a mistake or any answers that did not fit. The existence of these monitoring skills could deliver learners to control their own learning activities so that in the end they were able to learn the problem-solving process chemistry (Nbina & Viko, 2010). According to Schraw et al. (2006), monitoring or regulating involved understanding and awareness of the successful completion of the task performance, including the self-testing inside. Strategies that could assist learners in completing the learning task were very important. Learners' success depended on the ability to learn independently and monitor their own learning, so that learners should know the various learning strategies and when to use it with the right strategy. This was consistent with the findings by Pulmones (2007), that the manifestation dimensions of metacognitive monitoring could be in terms of revisiting the problem, looking back at problem solving, and checking progress against goals.

Another previous research showed that there was a significant correlation between metacognitive awareness with student performance. High metacognitive awareness of students made them capable of carrying out tests. Further results showed that there was no significant difference in students' metacognitive awareness of men and women (Rahman et al., 2010). Other researchers also concluded the same thing, that there was a relationship between metacognition with academic success, i.e. learners who had good metacognition appeared to have a high GPA. In addition, it was stated that the achievement of the objectives in accordance with metacognition affected GPA. Learners who could solve the goal were learners who had excellent metacognitive skills and strategies in mastering information, usually a superior usage of metacognition could improve GPA (Coutinho, 2007).

*Metacognitive self-regulation of reflection dimension*

At the final phase, subject did reflection by checking the settlement to assess whether the answer was correct and satisfactory, or revising if there was a shortage. Based on the analysis of the survey results revealed that the metacognitive self-regulation of reflection dimension grooved by the subjects of upper and middle groups in the evaluation phase (PS-4) was conducting an analysis molecular structure of $XeO_3F_2$(R-3). Both groups of subjects stated that the $XeO_3F_2$ molecule must have double bond which was contained in O=Xe=O so that formal charges were zero. Thus the electron pair repulsion between the substituent atoms (atomic oxygen) decreased. The placement of substituent atom in a trigonal bipyramidal structure depended on the electronegativity and the size of each substituent atom.

The opinions came from subject of two groups according to the statement of Muller (2006) which applied also for the O atoms occupying positions in an equatorial triangle with a greater angle ($120^o$) since the O atom was larger than the F atom, thus the O atom had lower electronegativity than F atom. Hence F atom was more electronegative, so the F atom occupied the axial positions. Subject in the upper group gave attention on the substituent atoms associated with formal charges. In trigonal bipyramidal of $XeO_3F_2$, the bond between Xe atoms with O atoms should be a double bond, so that the formal charge of Xe valued zero. It could happen so that the electron pair repulsion between the substituent atoms (atomic oxygen) was reduced (Muller, 2006).

According to Bound (Gama, 2004), assessment or reflection was an activity in which a person recaptured the experience, thought about it again, reconsidered and re-evaluated it. Someone who reflected or thought back to what he thought was not only good in understanding of what he knew, but also could make his own decisions to consciously learn to correct mistakes, while Woolfolk (1998) explained that the decision-making activity included assessment of the processes was generated by thinking and learning

outcomes. Research findings by Rahman et al.(2011) showed that the activity of reflection was able to increase the learners' metacognitive ability.

Learners thought about what was newly learned or thought backward about anything that had been done before in a reflection activity. Learners precipitated what they had learned as a new knowledge structure, in which it was an enrich mentor revision of previous knowledge. Thus reflection was related to the evaluation of the way he thought himself to be better in the future (Hacker et al., 2009). According to Pulmones (2007), the reflection, done at an evaluation phase, could be in term of rechecking the goal whether it had been achieved, reflecting which learning strategy was more efficient, assessing how learning strategies applied to other contexts, and rewarding yourself after studying or completing assignments. According to Schunk (Pulmones, 2007) metacognitive self-assessment was to decide the quality of one's work. This was a process of assessing the quality of the work based on the specified evidence and criteria. To achieve the desired goal, it required the active involvement of learners in the process and the development of metacognitive skills. Reflection was often not done because learners were less able to manage time during their study. It was within Rambusch's opinion (2006) which stated that doing reflection in learning could take a lot of time.

**Recommendations and conclusions**

The findings of this study indicated that in a planning dimension the upper group had a more carefully and thoroughly of metacognitive self-regulation groove for considering and using the initial knowledge to resolve the problem rather than the subjects in the middle and lower group. The upper group in monitoring used more knowledge, more closely, and more specific than the subjects in the group of middle and lower. Similarly, the dimension of reflection was only done by the upper and lower group. Metacognition became a learner's needs to understand how a task was done or completed, while cognition was the need to make task easier. Metacognitive self-regulation capacity was needed in solving the problem or task. Therefore it was recommended in the learning process: (1) training the metacognitive self-regulation skills of a planning dimension with emphasizing on meaningful learning in order to get learners used to select strategy, determine the allocation of resources, activate background knowledge, and arrange time; (2) training the metacognitive self-regulation skills of a monitoring dimension with emphasizing on the usage of information in the form of rules, formulas, equation, images, and associations with precision in problem solving so that learners were able to follow the proper understanding of task; (3) getting used to implement self-regulation skills of metacognitive on reflection dimension with emphasizing on digging existing knowledge to check the truth of the answers so that learners would have the ability to assess the process and outcomes of their own learning critically.

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