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METACOGNITIVE SKILL PROFILES OF CHEMISTRY EDUCATION STUDENTS IN SOLVING PROBLEM AT LOW ABILITY LEVEL

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ABSTRACT

The objective of this study was to categorize and describe the behavior of chemistry education students' metacognitive skills who had a low chemical understanding (low ability) in solving problems. The findings would be the basis of data for the development of instructional design on chemistry topics by utilizing metacognitive skill aspects. The subject of this study was two first-year students of chemical education, academic year 2016/2017 that joined a basic chemistry course at the low-level ability in Universitas Tadulako. Two subjects were picked through networking using a valid test comprehension. The subjects were determined regarding the percentage of low ability which was 87% of 79 students. The profile data of metacognitive skill were obtained through an essay test, think aloud and interview. The earned data were reviewed, grouped, encoded, and examined to see its credibility employing the method and time triangulation. The research found that both students of chemistry education having a low-level of basic chemistry adopted planning skills in solving problems which were the problem identifying, goal determining, and strategy managing. However, both did not use monitoring and evaluating skills.

Keywords: low level ability, metacognitive skills profile, problem-solving

INTRODUCTION

Chemistry is a discipline with the major purpose is obtaining an organized bunch of knowledge and skills in solving a problem. The problem-solving skills could be achieved if the solver has relevant knowledge and principles in mind (Cooper & Sandi-Urena, 2009). Therefore, problem-solving skills are influenced by students' understanding of materials dealing with problems and thinking process as a mental activity done by students to find solutions. Several researchers such as Dinsmore et al. (2008); Gauchon & Méheut, (2007); Levy Nahum et al. (2004); Bello et al. (2007); Bilgin et al. (2009) and Bunce (1993) stated that many students find it difficult in understanding and applying chemistry concepts. This is in line with the data reported by Cracolice et al. (2008), which showed students' average scores in problem-solving skills on Stoichiometry, Molarity, Density, and Ideal Gas were 9,8%; 22,5%; 41,1%; dan 42,9% respectively. In addition, a research conducted by Ijirana et al. (2013) showed that first-year chemistry students of Universitas Tadulako had an incomplete problem-solving structure of knowledge. This indicated that a lot of students faced difficulties in comprehending chemistry concepts and had low ability level in solving problems. They had some difficulties to perform the problem-solving skills such as compiling, monitoring and checking his/her thinking process when solving a problem.

One's knowledge to control his/her ability in arranging, monitoring, and re-examining his/her understanding and action in solving a problem are closely related to metacognitive skills. These skills are part of knowledge dimension, other than the factual, conceptual, and procedural knowledge that learners must possess (Anderson

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et al., 2001). Students having metacognitive skill indicate their ability to think about ideas explicitly and understand chemistry concepts well (Rompayom et al., 2010; Uzuntiryaki-Kondakci & Capa-Aydin, 2013). Cooper & Sandi-Urena (2009) said that metacognitive skills could help students understand chemistry well and improve their problem-solving skills. Moreover, Metalidou (2009) revealed that metacognitive skill refers to students' ability to plan the accomplishment of the objectives and the way of managing, monitoring, and modifying the problem-solving process. Therefore, a study of metacognitive skills in problem-solving process is important. The skills that need to be studied include planning, monitoring, and evaluating.

Students' metacognitive skill profiles indicate descriptions of chemistry students and difficulties they have that owe to their failure in solving problems. Those descriptions could be in the form of thinking level, understanding level on main materials of the problems, and concepts or other knowledge they need in order to solve problems. Therefore, knowing students' metacognitive skill profiles will facilitate lecturers to determine learning methods or strategies that should be applied to decrease students' difficulties. Thus, it is an urge to examine whether having students' metacognitive skill profiles could contribute to education world or not.

With this in mind, the researchers wished to find out forms of students' metacognitive skills based on the students' understanding as a mental activity in solving chemistry problems. The description was employed by lecturers to anticipate phenomena found in their classes, particularly when students solved problems as a manifestation of chemistry learning's purpose.

METHODS

This study was a basic research and used a qualitative descriptive method (Creswell, 2014). To obtain the research subject, a selection was conducted for students who attended the basic chemistry course in their second year of college, the academic year 2016/2017, chemistry education major in Universitas Tadulako. There were 79 students in the class of 2016/2017 who joined the grading test. The comprehension levels were divided into 3; high, medium, and low. The problems given on the grading test were 37 valid and reliable multiple-choice items. The researchers adopted Gilbert's (Dhindsa & Treagust, 2009) category of high at >75, medium at 60 ≤ and ≤ 75, and low at < 60.

The qualitative data collection was conducted to obtain the description of the students' metacognitive skill profiles in solving the problems. The research subject was randomly picked from low ability level students, who were given the symbol of S1, S2, S3, S4, etc. The subject was chosen in consideration with the highest understanding percentage (87% of 71 students), compared to other two levels of understanding.

The information about the students' metacognitive skills in solving the problems was obtained by giving problems to the S1 and S2 student. The given problems were adapted from Silberberg (2007) and were given the symbol of M1 and M2. The students solved the problems through think aloud (Olson et al., 1988; Ferguson et al., 2012) and triangulated the data through an interview. The interview was a combination of the structured and unstructured interview. The problems were assigned repeatedly at a different time (time triangulation) so that the students would consistently solve the problems. The explorative results of problem-solving using *think-aloud* along with interview were described and analyzed, referring to Miles et al. (2013) to obtain the students' metacognitive skill profiles.

RESULTS AND DISCUSSION

The analysis of the students' metacognitive skills in solving Chemistry problems, initiated by S1 and S2 in solving M1. A week later, both students had figured out the M2 (time triangulation). The triangulation results showed that there was a consistent meaning of the students (S1 and S2) in solving the problems at a different time. The consistency indicated that the students' data in figuring out M1 and M2 were credible. Hence, both students' metacognitive skill profiles appeared in M1 or M2.

The problems assigned to the students were; (M1) Vitamin C with a molar mass of 176,12 gr/mol is one of the hydrogen compounds which is naturally found in oranges. To determine vitamin C's molecular formula, some oranges are extracted so that it is obtained 5 grams of vitamin C. 1,00 gram of the sample is placed in a combustion chamber, which is as follows:

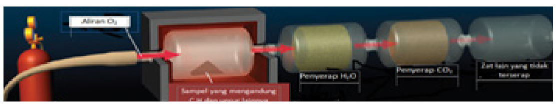

Figure 1. A Combustion Chamber

In the H_2O absorbent tube, 37,55 grams of $Mg(ClO_4)_2$ was used and in the CO_2 absorbent tank, 83,85 grams of NaOH was used. After the combustion, the mass of Mg $(ClO_4)_2$ turned to 37.96 grams and NaOH's mass turned to 85, 35 grams. a) make a plan to figure out the problem! b) finish by your plan! c) If you have solved the problem, check the results! Are you sure that your answer is correct? Leave a comment!; (M2) During the process of human physical activity, lactic acid with a molar mass of 90.08 grams/mol is formed in muscle tissue and causes muscle pain. An analysis is conducted to determine the molecular formula of lactic acid, shows that the compound contained 40.0% mass of element C; 6.71% mass of element H; and 53.3% mass of element O. a) make a plan to figure out the problem! b) finish by your plan! c) If you have solved the problem, check the results! Are you sure that your answer is correct? Leave a comment!

The elaboration of students' thinking processes in solving the problems to determine their metacognitive skills profiles describes as follows:

The Illustration of S1 in Answering the M1: *The S1's Planning Skill in Solving Problems*

The S1 read the M1 as directed by the researchers. After reading the problem, the S1 continued the statement in answering M1. Here are some excerpts of interviews with the S1:

Researchers: [have you understood the statement in the matter?]

S1 : explicitly answered that the problem is how to determine the formula of vitamin C molecules (while rewriting the problems given on the blank paper). S1 continued the assertion that the data available in this problem is mass ... mass (stammer), i.e. Mg $(ClO_4)_2$ and NaOH mass before and after the combustion of vitamin C. In addition, the mass of vitamin molecules C was known at 176.12 gram/mol. Other given data stated that the mass of vitamin C sample used was 1 gram. Here are the planning results made by the S1 during think-aloud:

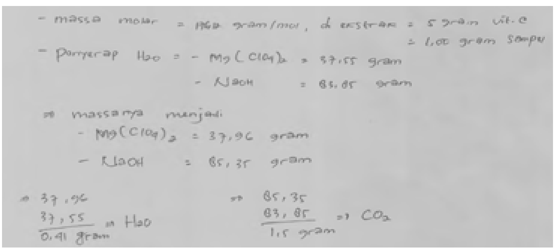

Figure 2. The S1's Planning Results

The statement expressed that S1 could translate part of the problem well by demonstrating his/her ability to identify the problem and objectives expected on M1. This result was the first step that would guide the S1 in solving the problem. According to Hacker et al. (1998); Metallidou (2009); and Balcikanli (2011), metacognitive skills are initiated by planning. Skills that may arise in the planning stage are setting goals and choosing the right strategy, and strategy made by S1 was;

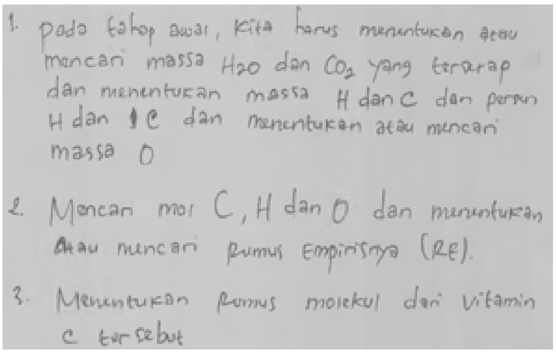

Figure 3. The S1's Strategy

The strategy formula given by the S1 showed that s/he understood what was needed in determining the molecular formula. This corresponded to the interview quotes in which the S1 stated that to determine the molecular formula, the empirical formula must be first determined.

The S1's ability to identify the data required in determining the molecular formula went along with his/her ability to construct a problem-solving strategy. Therefore, it said that the S1 could connect between what was known and what was needed in solving the problem. This situation is supported by the opinion of Sesen & Tarhan (2013) who stated that when learners are solving a problem, information about the problem (through understanding) is assembled into the working memory represented by a tree. One part of the tree contains 'known' while the other part involves 'unknown'. The long-term memory then looks for rules or relationships between the 'known' and 'unknown' in order to modify the working memory structure to achieve the solution to the problem. Searching for relevant information from memory occurs through two processes, which takes the information from long-term memory and decides whether or not the earned information is something necessary.

The S1 case showed that information could be drawn from long-term memory when there was a concept of empirical and molecular formula. The ability of S1 to relate the 'known' and 'unknown' (the goal achieved) is one of the causes of the S1's ability to develop problem-solving strategies resulting in goal achievement. This is in line with Sesen & Tarhan (2013) as described above.

The S1's Skills in Completing and Monitoring the Problem-Solving Process

The S1 answered the problem in accordance with the determined plan. The problem-solving process was done step by step until the empirical formula was determined. The following are given empirical formula (EF) determinations found in the S1's *think-aloud*:

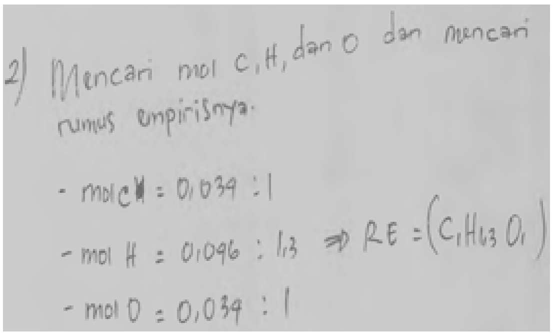

Figure 4. The Empirical Formula by the S1

According to the S1 (obtained from interview), the empirical formula is the smallest comparison of the atomic mole numbers of C, H, and O constituting the vitamin C molecules. This finding showed that the S1 only focused on determining molecular formulas and no longer monitored the empirical formulas obtained. The S1 basically could monitor the empirical formulas obtained by raising questions (Lazakidou & Retalis, 2010; Kaberman & Dori, 2009). The emerged questions could be 'Is it possible that there are at least 1.3 H atoms in the molecule?', 'Is there an atom in the number of fractions when it forms a bond with another element?'

These questions were not proposed by the S1 during the problem-solving process. It said that the S1 did not monitor the process of solving the problem even though the planning stage required monitoring and re-checking to achieve the expected results. This finding is in line with Desoete's (2007) opinion that monitoring skills are a one-man oversight activity against the cognitive strategies employed during the task performance in order to identify problems and modify plans. This monitoring activity cannot be separated from the planning and evaluation done by a person to be successful in solving a problem. Hacker et al. (1998) also reported that the metacognitive skill components such as planning, monitoring, and evaluation are interconnected or complementary to each other for achieving the goals.

The S1's Evaluation Skill in Solving Problems

The final results obtained by S1 was finding out molecular formula of vitamin C by comparing the vitamin C's molar mass with the empirical formula's molas mass discovered at the previous step. The following is given the final results of S1 through *think-aloud*:

The results of the problem-solving were then evaluated by the S1. The result of evaluation done by the S1 through *think-aloud* is as follows:

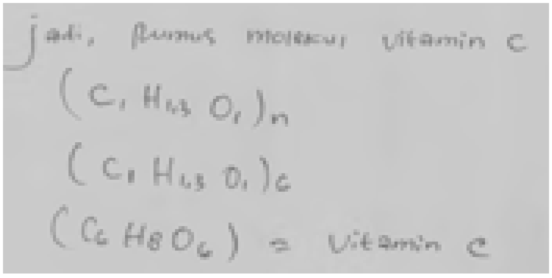

Figure 5. The S1's Final Results

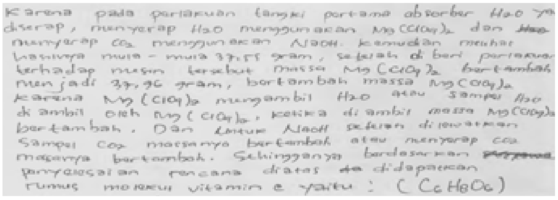

Figure 6. The S1's Evaluation Results

The reason given by the S1 was neither a proof of the truth accompanied by the logical reasoning of the solution nor the examining result in relation to the concepts involved in the problem. In line with this, Miller, et. al. (2009) stated that evaluation skill is the ability to contemplate to give consideration to a problem-solving process using a certain benchmark. Sesen & Tarhan (2013) also argued that the evaluation skill of problem-solving results could be measured from students' ability to use cognitive variables on connecting skills, which associates the concepts underlying a problem to convince the truth of the solution. The use of cognitive variables and logical reasoning is the key to predict subsequent success (Bunce & Hutchinson, 1993; Byars-Winstion & Fouad, 2008). The use of cognitive variables and logical reasoning is not an explanation of the relationship between the results and the problem of statement as performed by the S1. Therefore, the S1 had not done the evaluation skills.

The Illustration of the S2 in Answering the M1

The S2's Planning Skill in Solving Problems

The S2 read the M1 as directed by the researcher. After reading the problem, the S2 continued the statement in the completion of M1. Here are some interview excerpts and *think-aloud* on the S2:

Researchers: [have you understood the statement in the matter?]

S2 : Explicitly stated that s/he understood the problems given. The goal was to determine the molecular formula of vitamin C.

The steps done to accomplish the goal were:

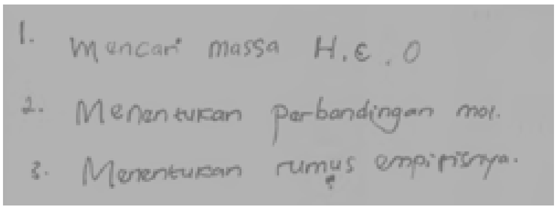

Figure 7. The S2's Planning Results

The S2 continued his/her statement that the provided data were employed to answer the question based on the steps which were as follows:

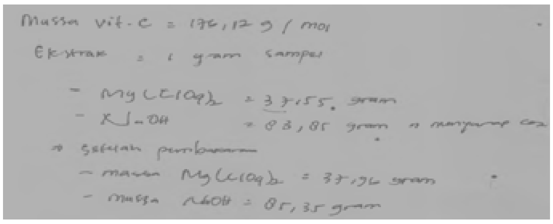

Figure 8. The S2's Strategy

The results of interviews and *think-aloud* showed that the S2 was able to explain the function of NaOH as a CO_2 absorber after repeatedly reading the problem. However, s/he could not explain the function of $Mg(ClO_4)_2$, since the S2 believed that the combustion process of Vitamin C only produced CO_2. Therefore, in the identification section of the problem, the S2 wrote the mass and function of NaOH but did not write the function of $Mg(ClO_4)_2$.

Based on the obtained results, it said that the S2 had not understood the matter well since s/he did not surely state that there were two compounds produced from the combustion of vitamin C, CO_2, and H_2O. Moreover, the S2 was known to lack of initial knowledge on combustion of a hydrocarbon compound so that s/he could not assimilate into his/her possessed knowledge and obtained knowledge. Therefore, there were four planning variables that the S2 had not achieved during the process i.e. problem-analyzing skill, conceptual linkage, idea association, and specific knowledge relevant to the problem. According to Sesen & Tarhan (2013), planning skills require six variables, namely; problem-solving skills, problem-solving experiences, conceptual interrelationships, idea associations, specialized knowledge, and specialized but irrelevant knowledge.

Seeing the above results, it shows that the S2 has had the problem-analyzing skill by demonstrating his/her ability in sequence, determining the expected objectives, selecting a settlement strategy, and identifying the problem. The sequence of thinking skills conducted by the S2 was a strategy to make it easier to solve the problem (a piece of information from interviews on the S2) even though the strategy prepared by the S2 was incomplete to answer the problem well. According to Desoete (2007), planning skills refer to the initial activity of one's thinking about how, when, and why s/he takes action to achieve the goal through a series of specific goals toward the main goal of the problem. This opinion supports the thinking skills of the S2. The S2 was expected to use planning skills by answering his/her own question such as "how to determine molecular formulas?". Another question predicted to appear in the S2 thinking process was "why should we do some actions in the strategy?" (Lazakidou & Retalis, (2010); Kaberman & Dori, 2009). This statement was corroborated by the interview results with the S2 that the molecular formula of vitamin C could be determined by discovering the empirical formula first. Therefore, the activity of preparing the strategy was done initially before deciding the supporting data required in solving the problem.

The S2's Skills in Answering and Monitoring the Problem-solving Process

The S2 tried to solve the problem according to the decided strategy but s/he did not do it structurally based on the steps made. The following is parts of the S2 in the problem-solving process.

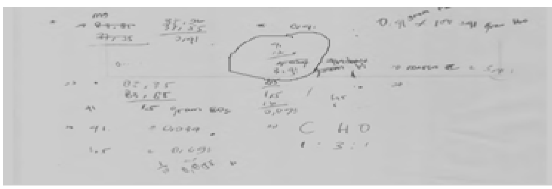

Figure 9. The S2's Problem-Solving Process

Based on the problem-solving data in the picture above, the S2 directly determined the mass of C and H from the calculation of the different mass of both absorbers used. The S2 had no idea that the difference was on the mass of CO2 and H2O instead of C and H. In addition, the S2 calculated and found a mass of C in a sample of 3.41 grams (in a circle sign). The S2 did not use his/her monitoring skills by logically thinking that the sample mass used was only 1 gram. Why does the C mass that is only a part of the vitamin C's atomic molecule have a far greater mass than the samples? Hacker et al. (1998) revealed that planning, monitoring, and evaluation, all three are interconnected or complementary to each other for the same goal. The inability of the S2 to plan as well as solve problem made s/he was also incapable of using monitoring skills because these skills are interconnected and complementary. In other words, the S2 was not skilled to solve the problem well.

The S2's Skills in Evaluating the Problem-solving Results

The S2 did not obtain the solution to the problem so as *not to use the evaluation skills to evaluate the problem-solving results*.

CONCLUSION

According to the result of the research, it concluded that chemistry education students with a low level of chemistry skills in solving a problem employed planning skill to identify a problem, to determine a goal, and to compile strategy. However, the students did not use the metacognitive skill of monitoring and evaluating since they tended to potentially fail to solve the problem.

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