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Received 26-10-2015 /Approved 30-11-2016

Delving students' metacognition based on reflective and impulsive cognitive style in problem solving about solubility.

Exploración de la metacognición de los alumnos basada en estilo impulsivo en la solución de problemas de la solubilidad

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Abstract.

This study aimed to explore students' metacognition in solving the solubility problem based on reflective and impulsive cognitive style. This qualitative research data included both documents of written tests and deep interviews. Subjects were students of a high school in East Java, Indonesia. The results showed that student with reflective cognitive style did metacognitive activities more systematically therefore they could solve the problem easily, considered all alternatives before making a decision, were able to make improvements, focused, and re-examined their activities. The subjects with impulsive cognitive style carried out metacognitive activities hastily in solving problems, not realizing that error had occurred, not analyzing for conformity with the objectives, not recognizing the mistakes so improvements were not possible, not considering the alternatives in making decisions, and not conducting an evaluation. This research was useful in designing learning strategies that aimed to optimize students' metacognition in solving problems.

Key words*: metacognition, problem solving, reflective and impulsive cognitive style.*

Resumen

Este estudio tuvo como objetivo explorar la metacognición de los estudiantes en la solución de los problemas de solubilidad y el estilo cognitivo de ellos reflexivo e impulsivo. Estos datos de investigación cualitativa incluyen, los datos de prueba escrita y entrevista en profundidad. Los estudiantes eran de una escuela secundaria en el este de Java, Indonesia. Los resultados mostraron que el estudiante con el estilo cognitivo reflexivo hizo actividades metacognitivas de manera más sistemática por lo tanto resuelven el problema fácilmente, consideradas todas las alternativas antes de tomar una decisión, pueden hacer mejoras, y volvieron a examinar sus actividades. Los estudiantes con el estilo cognitivo impulsivo llevan a cabo actividades metacognitivas no completas en la resolución de problemas, sin darse cuenta si se produjo el error, sin el análisis de la conformidad con los objetivos. Al fin no hacen mejoras, sin considerar las alternativas en la toma de decisiones, y no realizan una evaluación. Esta investigación fue útil en el diseño de estrategias de aprendizaje que tenían como objetivo optimizar la metacognición de los estudiantes en la solución de problemas.

Palabras clave*: metacognición, resolución de problemas, el estilo cognitivo reflexivo e impulsivo.*

INTRODUCTION

Cognitive learning style is an individual habit in information processing. Cognitive style explains the mode of someone's habit who is stable in perceiving, remembering, thinking, or solving problems. Cognitive style was usually characterized as a personality dimension which influences attitudes, values, and social interaction (Kozhevnikov, M., 2007, p. 464).

Cognitive styles of each student in processing and learning new information used different ways. For example, some individuals chose to learn by participating actively, while others chose to sit contemplatively and reflect on ideas or theories; several other individuals preferred to make a written record, while others preferred to use diagrams or pictures. This difference was called the learning style (Prajapati, B., et.al. 2011).

In teaching-learning teachers have to investigate and explore students' differences in order to adapt the education in accordance with the difference. Students will develop according to their respective capabilities. Teachers need to provide a cognitive problem that leads to conflict and curiosity of students, thus encouraging students to solve it themselves. Students will observe, assess, and connect it with their initial knowledge. This action is a self reflection that requires skill to design, monitor, and assess learning process that is defined in the form of self problems against the phenomena around them. Students also need to embed, or change the way they think at the same time. Any processes that determine answers or make decisions affect students' mastery and implementation of metacognitive processes.

According to Sandi-Urena, S. (2008), there are two main metacognition components generally identified: metacognitive knowledge (or knowledge of cognition,) and metacognitive skillfulness (or regulation of cognition.) Knowledge of cognition refers to the awareness of the individuals about their cognition, that is: knowing about things (declarative knowledge), knowing how to do things (procedural knowledge) and knowing why and when to do things (conditional knowledge).

The knowledge of students' metacognition becomes a benchmark of students' ability in solving chemistry problems. Chemical problem solving skills with a variety of different ways are influenced by cognitive styles such as reflective and impulsive cognitive style.

This study used solubility and solubility product problem solving which contained conceptual and procedural knowledge. Conceptual knowledge was regarding to the relevance of concepts including the concept of chemical equilibrium, electrolytes, concentration, and temperature, while procedural knowledge was related to the phase or sequences of work which are required for certain concepts. The characteristics of these materials were according to the students' metacognitive skills component that included planning, monitoring, and evaluating. Schunk and Zimmerman (1994) suggested that learners with high metacognitive ability knew whether they had completed or not in controlling the academic tasks and could customize their learning. According to Pulmones (2007) that prolonged engagement of students in classroom activities designed in a constructivist environment gives ample opportunities for students to demonstrate their overt planning, monitoring and evaluation behaviors. Purposely asking students to answer metacognitive questions afforded them the opportunity to reflect on their thinking, thus fostering their metacognition.

METHODOLOGY

This type of research was qualitative in which its data were in the form of written tests results and in-depth interviews to study subjects' reflective and impulsive cognitive style. Determination of cognitive styles used the instrument Matching Familiar Figure Test, MFFT (Warli, 2010). The subjects of this study were students of a school in East Java Province, Indonesia.

Based on the MFFT results, it was found that 17 students had reflective cognitive style and 7 had impulsive cognitive style, 3 students had fast accurate cognitive style while 4 had slow-inaccurate cognitive style.

In this study, the activity of metacognitive processes used indicators of planning, monitoring, and reflection dimensions (Nugrahaningsih, 2011). Problem solving phases were: understanding the problem (PS-1), devising a plan (PS-2), carrying out the plan (PS-3), and looking back (PS-4) (Polya, G., 1973).

Selection of subjects was based on field notes, MFFT results, the results of written tests and interviews. Selection of subjects was done repeatedly to prospective subjects to obtain consistent interviews results.

The selected research subjects numbered 4, namely 2 subjects with reflective cognitive style that was the subject of R-01 and R-02, and 2 subjects with impulsive cognitive style that was the subject of I-01 and I-02.

Data analysis which divided into three processes: data reduction, data display, and conclusions (Miles & Huberman, 1994). To test the validity of the data, this research used triangulation method (Lincoln & Guba, 1985).

RESULTS

Problems to be solved by the subjects were:

- Problem 1: A total of 11.6 mg of magnesium hydroxide can be dissolved in 100 mL of water. Express the solubility in mol/L and determine the solubility product constants.
- Problem 2: Calculate the solubility Ag_2CrO_4 (Ksp Ag_2CrO_4 = 1.6 x 10^{-12}) in 0.1 M $AgNO_3$ solution.
- Problem 3: Given solubility product constant of $Mg(OH)_2$ = 3.2 x 10^{-8}. Determine the solubility of $Mg(OH)_2$ in pH 12 solution.
- Problem 4: The solution of 500 mL K_2SO_4 0.001 M are added into the solution of 500 mL $CaCl_2$ 0.001. If Ksp $CaSO_4$ = 2x10^{-5}, will precipitation be formed?

Based on the results of triangulation to the written answers and interviews obtained the following valid findings.

Metacognition of subject R-01 with reflective cognitive

Understanding the problem (PS-1). Subject R-01 wrote what was known (P-1), for example mass of $Mg(OH)_2$ 11.6 mg, volume of solution 100 mL, and the relative atomic mass (Ar) H, O, and Mg, then subject wrote what was asked (P -2), those were solubility (s) and the solubility product constant (Ksp), and determined the objectives (P-4) which were to calculate s and Ksp. Subject R-01 also examined the suitability of notations m, L, s, and Ksp that were used (M-3), as well as connecting with the concept (E-4) of solubility and solubility product.

Devising a plan (PS-2). Subject R-01found a relationship between the data and question (P-6), so that he gained something useful from the data (P-7), then he determined the required prior knowledge (P-8) which was the moles concept used in calculation. He also planned a solution (P-10) to determine the solubility formula and solubility product used at each step (P-11). Besides that, he could alter unknown data so close to the known (P-14), by determining the relative molecular mass (Mr) from the known relative atomic mass (Ar) to calculate the mole. He also calculated the mole in advance to calculate the solubility (E-7).

Carrying out the plan (PS-3). He (R-01) prepared the next steps (P-15) by calculating the moles, s, and Ksp so that he could determine the results (P-18) that s = 2 x 10^{-3} mol / L and Ksp = 3.2 x 10^{-8}. Additionally he examined the possibility of an error in a step (M-10) and checked the accuracy of calculation step by step (M-11). This could be seen when he entered the data into the formula that was used, then carried on an evaluation to analyze conformity with the objectives (E-12) shown in the underlined final result answers.

Looking back (PS-4). Subject R-01 checked the truth of the results (M-17), re-examined the truth of the answer (M-21), convinced himself that his evaluation was true (E-17), and evaluated the achievement of goals (E-18).

Metacognition of subject R-02 with reflective cognitive style

Understanding the problem (PS-1). Subject R-02 wrote what was known (P-1), namely the mass of $Mg(OH)_2$ 11.6 mg, 100 mL of water, and Ar H, O, and Mg, then he wrote what was asked (P-2), which was s in mol / L and Ksp, and determined the goal of problems (P-4) which was calculating the solubility in mole and solubility product value. He also examined the suitability among the used, the known, and the asked notation (M-3) namely s for solubility, until he could connect the concept (E-4) of solubility and solubility product.

Devising a plan (PS-2). Subject R-02 found a relationship between data and question (P-6), until the subjects got something useful from the data (P-7). He also chose required prior knowledge (P-8) that was concept of the mole used in the problem solving. He found a plan of problem solving (P-10) to determine the formula used at each step (P-11), using the solubility and solubility product formula. Other than that he could change the unknown data until close to the known (P-14), which was calculating the mass of the molecule relative (Mr) from the known mass of the atom relative (Ar) and converting units of milligrams to grams for calculating the mole, and units of milliliters to liters. He counted the mole before calculating the solubility and solubility product according to the indicators. If he could not solve the proposed problem, then he attempted first to solve the related problems (E-7).

Carrying out the plan (PS-3). Subject R-02 prepared the next steps (P15), which were calculating the mole, s, and Ksp, and then determined the result (P-18) in which s = 2x10^{-3} mol/L and Ksp = 32x10^{-9}. He also performed monitoring activities to control the possibility of an error in a step (M-10) and check the accuracy of calculation step by step (M-11) while entering the known data into the formula that was used, and evaluated conformity with the objectives (E-12) characterized by the underline on the final result answers.

Looking back (PS-4). Subject R-02 checked the truth of the results (M-17), re-examined the truth of the answer (M-21), convinced himself that the evaluation was correct (E-17), and evaluated the goals achievement (E-18).

Based on the above findings, a relationship scheme between the problem solving phase and metacognition activities by subjects with reflective cognitive style could be arranged as shown in Figure 1.

Activities of Metacognition Subject R-01	Problem Solving Phases	Activities of Metacognition Subject R-02
Planning	Understanding The Problem (PS-1)	Planning
P-1, P-2, P-4		P1, P-2, P-4
P-6, P-7, P-8, P-10, P-11, P-14		P-6, P-7, P-8, P-10, P-11, P-14
P-15, P-18		P-15, P-18, P-19
Monitoring	Devising A Plan (PS-2)	Monitoring
M-3		M-3
M-10, M-11		M-10, M-11
M-17, M-21		M-17, M-21
Evaluation	Carrying Out The Plan (PS-3)	Evaluation
E-4		E-4
E-7		E-7
E-12		E-12
E-17, E-18		E-17
	Looking Back (PS-4)	

Figure 1 Schematic Relationship for Solubility Problem Solving and Activities of Metacognition by Reflective Cognitive Style Subjects

Metacognition of subject of I-01 with impulsive cognitive style

Understanding the problem (PS-1). Subject I-01 wrote what was known (P-1), the mass of $Mg(OH)_2$ 11.6 mg, the water volume of 100 mL, wrote what was asked (P-2), namely solubility and determined the objectives (P-4) namely calculating solubility.

Devising a plan (PS-2). Subject I-01 planned to obtain the solution (P-10), set the formula that was used in every step (P-11), namely the mass per volume, hence he did not recognize the mistakes that had been made.

Carrying out the plan (PS-3). Subject I-01 prepared the next steps (P15), then checked the accuracy of calculation step by step (M-11) by entering data on the formula used in calculation, so as to determine the results (P-18) of solubility, s of 0.116 mol/L but he did not control the occurrence missteps.

Looking back (PS-4).Subject-01 did not re-examine the work results, because until the end of his work, he did not recognize the mistakes he had made.

Metacognition of subject of I-02 with impulsive cognitive style

Understanding the problem (PS-1). Subject I-02 to wrote what was known (P-1), the mass of $Mg(OH)_2$ 11.6 mg, volume 100 mL H_2O, wrote what was asked (P-2), namely solubility and Ksp then set goals (P- 4) namely calculating solubility and Ksp.

Devising a plan (PS-2). Subject I-02 planned to obtain the solution (P-10) to determine the formula used in each step (P-11), namely by multiplying the mass to the volume, but he did not recognize the mistakes made.

Carrying out the plan (PS-3). Subject I-02 prepared the next steps (P15), checked the accuracy of calculation step by step (M-11) by entering data into the available formula, until he assigned the obtained result (P-18) at 11.60. However, he did not control the missteps that had been done, so he did not correct the occurred mistakes.

Looking back (PS-4). Subject I-02 did not check the truth of the results that had been obtained.

Based on the above findings, a scheme of the relationship between problem solving phase and metacognition activities by impulsive cognitive style subjects could be arranged as shown in Figure 2.

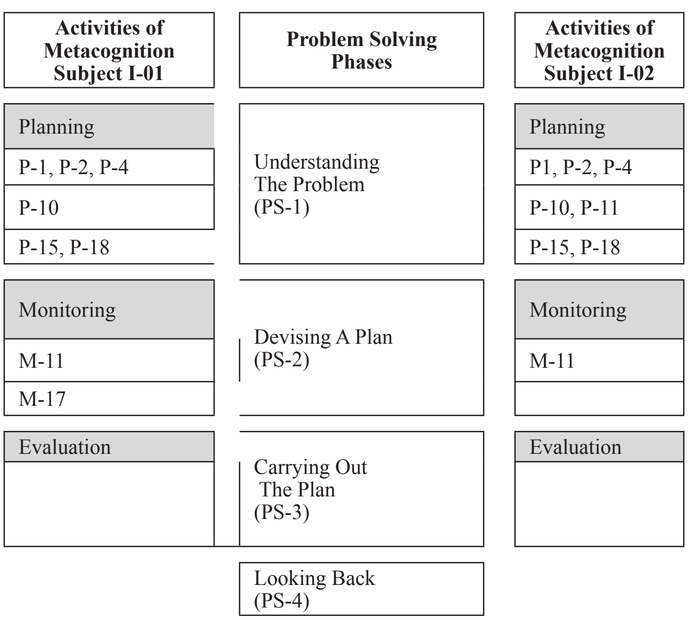

Figure 2 Schematic Relationship for Solubility Problem Solving and Activities of Metacognition by Impulsive Cognitive Style Subjects

DISCUSSION

The influence of metacognition on learning and problem solving has been demonstrated, and it is becoming increasingly clear that promoting metacognitive activity can produce substantial improvements in problem solving and learning in chemistry (Cooper, M.M. and Sandi-Urena, S., 2009). Subjects with reflective or impulsive cognitive style on the phase of understanding the problem, starting the completion by writing what was known and what was being asked. According to Bereiter and Scardamalia, Gordon, and Perry (Hamman, 2005, p. 15-26), writing meant the subject determined his attitude to plan what to do, including content/material, as well as the source of knowledge that was used. This was in line with views expressed by Pulmones (2007), if metacognitive activity for the planning dimension in problem solving were carried out we might be thinking and writing what was known, and identifying information that was not yet known. Both of the groups understood the problem and determined the destination also. According to Jacob and Paris (Jbeili, 2003: 64), the cognition arrangement component of the planning dimension including goal setting, activating the relevant resources, and selecting appropriate strategies. Subjects R-01 and R-02 also performed monitoring of metacognition activity, i.e. checking the notation (?) suitability used with the known and questioned. This is consistent with that expressed by Woolfolk (1998) that in this activity the subjects performed monitoring which was the subject's awareness of how to do cognitive activities. At this phase, the subject of R-01 and R-02 pulled out evaluation of metacognition activity which connects to a concept. These activities were in accordance with that expressed by Bound (Gama, 2004), that reflection depicted an activity in which a person "recaptures experiences, rethinks, reconsiders, and reevaluates". A student who reflected or rethought not only had a good understanding of what he knew, but also could make his own decisions consciously to improve what they knew.

At the phase of planning solutions, R-01 and R-02 could find a relationship between the data and the question, thus the subjects would gain something useful from the data. This was consistent with research findings, that metacognition is an essential element in a student's development of solution plan (Flavell, 1976). Students needed metacognition in order to realize and connect the information that had been known to question the problem so they could build a solution plan. This activity indicated that the subject who had a reflective cognitive style had developed a plan of action that could answer questions on them, such as: what kind of knowledge can help accomplish this task? Which way will my thinking take me? What should I do first? (NCREL, 1995).

At the phase of planning solutions, the subjects with both reflective and impulsive cognitive styles obtained a solution plan, ranging from determining the equilibrium reaction, to seeking solubility and its Ksp value by setting the formulas used in each step. Such activities according to Flavell (Desoete, 2001) are strategies of variable metacognitive knowledge, namely knowledge of how to do things, how to overcome the arisen difficulties, or how to achieve the target. Subjects of the reflective group could also change the unknown data so as to approach the known. This is consistent with Woolfolk (1998) that what to use, what sources to collect, how to start, and which to follow or implement first were included in metacognitive skills of planning. If subjects could not solve the proposed problem, they would first try to figure out the related problem in accordance with that purpose. (Woolfolk (1998)) The evaluation activity contained decisions making about the process generated by the ideas and learning.

At the phase of planning based problem solving, subjects R-01, R-02, I-01 and I-02 made up the next step, so as to determine the results of the measures that had been carried out. According to Polya (1973), problem solving is an attempt to find a way out of a difficulty, to achieve a goal that was not easy enough to be reached immediately. It was indispensable in answering questions to find a way out so that the problem could be solved to achieve a typical goal.

At this phase also, in addition to planning activities, R-01 and R-02 also performed monitoring activities. Both subjects controlled possible errors on a step, but the subjects I-01 and I-02 did not recognize an error in the plan that had been made, therefore they did not correct those mistakes. According to Woolfolk (1998), in this activity subjects performed monitoring which was a form of subject's awareness of how to do a metacognitive activity. Monitoring metacognition activity that was conducted by reflective or impulsive subjects at the completion phase was checking the accuracy of calculation problems step by step. According to Jacob and Paris (Jbeili, 2003: 64) monitoring included examining one's progress and choosing the appropriate improvement strategies when the previous selected strategy was not working properly. In addition to planning and monitoring activities, the subjects R-01 and R-02 in the phase of plan based problem solving also undertook the evaluation activity, which analyzed the conformity with the objectives. This was in accordance with Pulmones (2007) that the activity to assess was the activity of rechecking whether the objectives had been achieved.

In the last phase namely re-examining the results obtained subjects R-01, R-02 and I-01 took activity monitoring activity, by checking the accuracy of results. According to Jacob and Paris (Jbeili, 2003, p. 64) monitoring included examining one's progress and chooosing the appropriate improvement strategies when the previous selected strategy did not work properly, while Rickey and Stacey (2000) suggested that by applying metacognitive activities, the dimensions of monitoring and regulation/setting aable student could increase success in solving problems. Both subjects also re-examined the truth of their works. Evaluation activities were also carried out by R-01 and R-02 in the form of convincing themselves that the evaluation was correct and evaluating the achievement of objectives. According to Pulmones (2007), the activity of assessing was an activity to recheck the achieved objectives. This was in line with that expressed by Bound (Gama, 2004) that the reflection depicted an activity where a person recaptures experiences, rethinks, reconsiders and reevaluates.

Subjects who have an impulsive cognitive style tend to immediately end settlement of a problem and not to evaluate. That is an appropriate opinion since evaluating learning takes a lot of time (Rambusch, 2006). Lin (2001) reinforces these conditions that, students' difficulties aside, time for metacognitive reflection is an issue if the environment does not respect and does not support such activities.

CONCLUSIONS

Subjects who have a reflective cognitive style in solubility problem solving use metacognitive activities: planning, monitoring, and evaluation. Subjects pull out more detail in carrying out the task, give the information in a structured form, read to understand and interpret the problem, determine their own learning objectives, and focus on relevant information. Subjects consider all alternatives before making a decision, tend to be more cautious in making decisions, pick up a more systematic way and with a high awareness in solving problems. Subjects who have reflective style focus in problem solving, and check the already done activities.

Students who have impulsive cognitive styles tend to use less metacognitive activities. Subjects take decisions quickly without thinking deeply, are less careful in taking decisions and tend to solve a problem quickly, so they were less aware of any mistakes made.

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Received 16-01-2016 /Approved 30-11-2016

Simulando estequiometría con la hoja de cálculo: uso de la barra de desplazamiento

Simulating stoichiometry with spreadsheet: use of the scroll bar

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Resumen

Se presenta una secuencia de actividades para enseñar estequiometría con sencillas hojas de cálculo que incorporan como recurso interactivo a la barra de desplazamiento. En esta propuesta alternativa a la resolución rutinaria de ejercicios, los estudiantes se encuentren motivados y activos confeccionando simulaciones numéricas y respondiendo preguntas del tipo ¿"qué pasa si...? La visualización simultánea de las cantidades experimentales iniciales y finales, y de la relación estequiométrica, permite hacer frente a concepciones alternativas de los estudiantes.

Palabras clave: *estequiometría, enseñanza, simulación, hoja de cálculo, barra de desplazamiento*

Abstract

A sequence of activities is presented for use in the teaching of stoichiometry by means of simple spreadsheets that have the scroll bar incorporated as an interactive resource. Using this method as an alternative to routine ways of doing exercises, students will become more motivated and active, setting up numerical simulations and answering questions like "What happens if...?" Simultaneous visualization of initial and final experimental quantities, and of the stoichiometric relation, makes it possible to deal with students' alternative conceptions.

Keywords: *stoichiometry, teaching, simulation, spreadsheets, scroll bar*

INTRODUCCION

La estequiometría es uno de los núcleos conceptuales centrales de la química dado que se ocupa de los aspectos cuantitativos de la reacción química. Por su complejidad los estudiantes presentan dificultades que van más allá de cuestiones matemáticas (como el dominio de la proporcionalidad) y mantienen concepciones alternativas luego de la enseñanza. Esto se debe a que la estequiometría aborda las relaciones cuantitativas de la