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# Study of Metacognitive Knowledge on Acid-Base Topic Implemented through Process-Oriented Guided-Inquiry Learning (POGIL)

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**Abstract**

One of the chemistry topic studied in senior high school is acid-base chemistry. This topic involves three-level framework of macroscopic, microscopic, and symbolic representation that tend to be understood by students who have an ability to inter-relate their knowledge to these levels of representation. Conscious inter-relating of knowledge among the three aforementioned levels of representation requires some abilities such using information correctly, doing task step by step efficiently, and evaluating knowledge reflectively. Results of several studies reported that lack of ability to inter-relate knowledge among macroscopic, microscopic, and symbolic representation along with improper usage of certain knowledge have led to fragmented understanding and misconception. These problems can be overcomed by promoting metacognitive knowledge regarding chemistry learning. Metacognitive knowledge is knowledge about self-cognition which consists of declarative knowledge, procedural knowledge, and conditional knowledge. Abilities to correctly acquiring and using information, efficiently doing task step by step, and reflectively evaluating knowledge, consecutively are definition of declarative, procedural, and conditional knowledge. By this time, acid-base learning is dominated by verification approach, in such way means it doesn't engage students to develop metacognitive knowledge in relation to how students declare knowledge in their memory, construct the concept in right procedural manner, and evaluate the acquired concept. Process-Oriented Guided-Inquiry Learning (POGIL) is one of guided inquiry learning verse that can be expected to develop metacognitive knowledge. Each activity of POGIL has a syntax of five stages: orientation, exploration, concept formation, application, and closure. Metacognitive knowledge can be developed in each stage. Some arguments and several conceptual studies declare that POGIL enables students to develop metacognitive knowledge if syntax of guided inquiry is set correctly. In this conceptual article, the effort for developing metacognitive knowledge on acid-base topic is administered to learning material product by form of POGIL students' workbook.

**Keywords:** metacognitive knowledge, acid-base, POGIL

## Introduction

Metacognition is one component of self-regulated learning theory. Flavell (1979) defines metacognition as knowledge of self-cognitive processes and products, thinking about one's own thinking. The two components of metacognition are

metacognitive knowledge and metacognitive regulation, each of which has three sub-components (Flavell, 1979; Schraw&Moshman, 1995; White &Frederiksen, 1998; Veenman, 2006). Metacognitive knowledge is one's knowledge of cognition, memory, and self-comprehension (Schraw&Moshman, 1995:352; Handel *et al*., 2013:165).The sub-components of metacognitive knowledge are declarative knowledge, procedural knowledge, and conditional knowledge.

Metacognitive regulation is the ability to control the process of learning and strategic efforts in solving problems. Sub-components of metacognitive regulation are planning, monitoring, and evaluating. Rickey & Stacy (2000: 915) argue that chemistry learning requires metacognition for two reasons: (1) developing thinking ability, and (2) determining the success of the problem solving process. In general, metacognition is the key to learning that is deeper, durable, and applicative. Thomas & Anderson (2014: 140) argues that metacognition in chemistry is required in the ability to reason and interrelate comprehension at three levels of macroscopic, microscopic, and symbolic representations. Therefore, it takes the conscious ability to interconnect these three levels of representation with regard to chemical phenomena. To facilitate the students to the maximum cognition, it takes effort to develop and improve metacognition relating to the thought process involved.

**Expert View of Metacognitive Knowledge on Learning**

Some views on the concept of metacognitive knowledge has been initiated by the experts.Among them are Flavell, Schraw&Moshman, and Veenman.

*Metacognitive Knowledge Concepts According to Flavell*

Flavell (1979) argues that metacognitive knowledge is a segment in which one's knowledge is stored in the form of cognitive objects of knowledge, task, goal, activity, and experience. For example, a person can be more adept at completing an algorithmic task than a conceptual assignment because in his mind segment stores more formulas and calculations. Three categories of metacognitive knowledge by Flavell (1979) is a self-knowledge, task, and strategy. The person category includes self-confidence as a stimulus of cognitive activity.This category can be further

divided into intra-individual differences, interindividual differences, and universal cognition. An example for subcategories of intra-individual differences and interindividual differences is the belief that one can learn better by listening rather than reading. A person can also find out that he is more socially sensitive than others. An example for a subcategory of universal cognition is that one can learn through various means and levels such as observing, remembering, communicating, or solving problems.

Categories task is an understanding of the organization of cognitive activity in an effort to achieve the goal. This category relates to how to choose a more cognitive activity needed and easier though given the same information. For example, it is easier to retell a knowledge than to write it down. The strategy category deals with which knowledge and strategies are most effective in achieving goals in the cognitive process.For example, one can learn well when giving more attention to the main points and trying to repeat it in its own language. In this case it means someone can give a reason why a cognitive activity is chosen in the learning process.

*The Concept of Metacognitive Knowledge According to Schraw & Moshman*

Schraw & Moshman (1995) define metacognitive knowledge as what one knows about self cognition. The metacognitive knowledge category according to Schraw & Moshman (1995) is declarative, procedural, and conditional knowledge.Declarative knowledge is self-knowledge as a learner of a number of definitions and strategies in learning along with the factors that influence it (Schraw & Moshman, 1995). For example, adults have more knowledge in his memory than children so adults tend to be more competent in responding to a problem. So it is with a student who can better use his memory than any other student.

Procedural knowledge is a person's knowledge of the steps used to solve problems. A person with a high level of procedural knowledge is able to use skills more automatically, strategize effectively, and use different strategies to solve problems.Procedural knowledge have a role an important role in problem solving skills. Conditional knowledge is knowledge of when and why a number of cognitive

activities are used. Conditional knowledge can be interpreted as a declarative knowledge of procedural knowledge.For example, learners with a good level of conditional knowledge are more careful in accessing specific learning needs so as to determine when a strategy is appropriately used in solving problems and understanding why a problem should be solved through the strategy.

*Metacognitive Knowledge Concepts According to Veenman*

Veenman (2006) associates cognition with metacognition by analizing that cognition is an ability in object level, whereas metacognition is the ability to organize the object. There is two way information between the object level and the meta level.Information about object level is transmitted at the meta level through monitoring process, while instructions from the meta level are transmitted at the object level through the control process. So, if an error occurs at the object level, the monitoring process will alert the meta level and the activated control process to solve the problem. Metacognitive knowledge according to Veenman (2006) deals with the knowledge retrieval of memory which consists of declarative knowledge and conditional knowledge.Declarative knowledge is divided into person's knowledge of the interaction between self, task, and strategy characteristics. For example, one can think (self-characteristic) that he or she is incompetent in doing the task through calculation (characteristic of the task) so he decides to work on the problem through a conceptual approach (strategic characteristic).Declarative knowledge is often associated with metamemory. Another component of metacognitive knowledge is the related conditional knowledge about when a strategy is done 'what to do when' and is often associated as metacognitive awareness of declarative knowledge.

*Comments About Metacognitive Knowledge Expert View*

The concept of metacognitive knowledge according to Flavell, Schraw&Moshman, and Veenman is essentially no different. All three argue that metacognitive knowledge is related to one's knowledge of the cognitive object it possesses.Declarative knowledge is knowledge of something, knowing about something. Procedural knowledge is knowledge of how to do something, knowing

how to do something. Conditional knowledge is knowledge of when and why something is used, knowing when and why something has been done.The difference, Flavell and Veenman explicitly explained that the three components of metacognitive knowledge are interrelated in solving a problem, task, or problem, while Schraw&Moshman describes independently the role of each component of the metacognitive knowledge. The advantages of Schraw&Moshman are related to the definition. It is important for the development of an instrument for independently measuring each metacognitive knowledge, so that correlations between metacognitive knowledge can be analyzed in depth.

**The Metacognitive Knowledge Necessary to Understand the Acid-Base Topics**

Acid-base topics are closely related to history and its change from time to time (de Vos& Pilot, 2001). These characteristics are represented by an understanding of the Arrhenius, Bronsted-Lowry, and Lewis acid-base theories studied at the SMA/ MA level.Arrhenius acid-based are limited to substances that can produce H + and OH– ions, the Bronsted-Lowry acid-base concept emerges as the accommodation of the transfer of H + particles that determine the acid-base properties. Lewis's acid-base concept then appears to accommodate the presence of acid-base reactions involving the transfer of free electron pairs (PEB).At the college level, the principal concept of acid-base Lux-Flood appears on the oxide transfer and the acid-base concept of a solvent system based on the cation and solvent characteristic anions. New models and concepts are introduced to give a better reality description (Drechsler& Schmidt, 2005: 20).To master the development of acid-base theory requires good declarative knowledge. Declarative knowledge is needed to compare the acceptance of old concepts with new concepts as well as to select appropriate concepts in solving acid-base topic problems.

Acid-base topics study the equilibrium of static and dynamic solutions so that the topic includes three levels of macroscopic, microscopic (atomic, molecular, ionic), and symbolic representations (Nakhleh, 1994; Catalayud et al., 2007). Students

'difficulties in understanding acid-base topics can be caused by students' inability to transition understanding between macroscopic, microscopic, and symbolic representations, potentially leading to misconceptions and even misconceptions.Macroscopic representations relate to sensable concepts such as acid-base solutions and the identification of acid-base properties using litmus paper or sense sensors. Microscopic representation is used to describe material models in particulates and kinetic, while symbolic representation is related to the equation of reaction describing chemical phenomena (Nakhleh, 1994: 1).For example, Arrhenius acid is a substance that produces H + ions in solution. Therefore, it is necessary to understand that the ions are small charged particles resulting from the dissociation of the compound in the solution. The dissociation process can be represented symbolically using the following reaction equation.

$$HCl(aq) \longrightarrow H^{+}(aq) + Cl^{-}(aq)$$

Students should be able to use information networks in each representation to organize and display their knowledge, since students are constantly required to switch between representational systems when making chemical reasoning on acid-base topics (Nakhleh, 1994: 1).The ability to connect between representations is termed integrated understandings. An integral understanding involves a number of components of metacognitive knowledge.Procedural knowledge is required to perform reasoning steps at three levels of representation, whereas conditional knowledge is required to display the exact chemical knowledge of some information and procedures.For example, metacognitive knowledge is required to associate symbolic representations with the microscopic between strong and weak acids as follows.

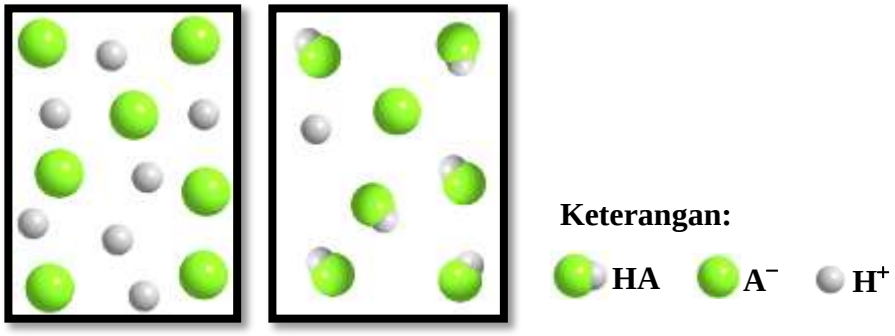



Fig. 1. Microscopic representations (a) strong acids and (b) weak acids

Based on the description, it can be concluded that good metacognitive knowledge is required in understanding the acid-base topic.

**Metacognitive Knowledge in Process Oriented Guided-Inquiry Learning (POGIL)**

POGIL is one of the guided inquiry learning version. Inquiry activities can trigger students to involve metacognitive knowledge (Kipnis & Hofstein, 2007).Students in guided inquiry activities construct new ideas based on prior knowledge and experience, gain knowledge in accordance with self-mental activities, interact, learn about effective learning strategies, determine appropriate learning needs, understand tasks, monitor progress of the task, reflect and assessment of a number of strategies (Baird & White, 1996; Kardan & Hameed, 2016: 39). If the inquiry is properly arranged, it can produce the desired level of metacognition.

There are a number of arguments that POGIL can develop metacognitive knowledge. POGIL creates awareness and understanding of the thinking process and the use of a number of strategies during the learning process (Kardan & Hameed, 2016: 39).POGIL also creates a metacognitive activity that students are managing and monitoring their self-regulatory, self-assessment, and reflection on what they have learned and do not yet understand (reflection on Learning) (Hanson, 2006).Metacognition generates a critical thinking atmosphere about student involvement in the learning process. Students need to recognize when to understand the concept and apply it to solve new problems.Students are asked self-questioning as

to whether I have all the information, whether I have used the right strategy, and whether there is a better strategy alternative.

**POGIL's Workbook for Developing Metacognitive Knowledge on Acid-Base Topics**

Kardan & Hameed (2016: 41) argues that there is metacognition involvement in each stage of POGIL. In this paper, the product developed is POGIL Workbook.The involvement of metacognitive knowledge at each stage of POGIL and its presentation examples on the Arrhenius acid concept is described as follows.

1. Orientation

   Metacognitive knowledge at the orientation stage is involved in the process of acquiring early knowledge of students about previously learned concepts. At this stage, the metacognitive knowledge developed is declarative knowledge.The guiding questions provided encourage students to recall declarative memory of understanding the concept of the solution, the acidic nature of a substance, and the way of its identification.

   Simulation:

   Look at the following figures!

**(a)** **(b)** **(c)**

Fig. 2 (a) Lime; (b) Grape; dan (c) Tomato

(I) Have you ever tasted the fruits in Figure 1.1? When the fruit is juiced, filtered, then drunk, how does it feel?

(II) Have you ever tasted pickles? How does it feel? What causes the acidic taste of the pickle?

Look at the following picture!

Fig. 3. Vinegar acid

(III) Can the vinegar acid in Fig.3 be tasted? How safe is it to identify it? What are the properties of the identification result?

(IV) Although different in appearance and way of identification, the substances in Fig 1 and Fig 2 all have acid properties. Why is that?

2. Exploration

At this stage, metacognition is involved in the form of cognitive knowledge in the process of discovering patterns that are given visually, auditory, or kinesthetic. Attempts to analyze patterns and collect information provided required declarative and procedural knowledge.

Simulation:

Given Beaker glasses (1), (2), and (3):

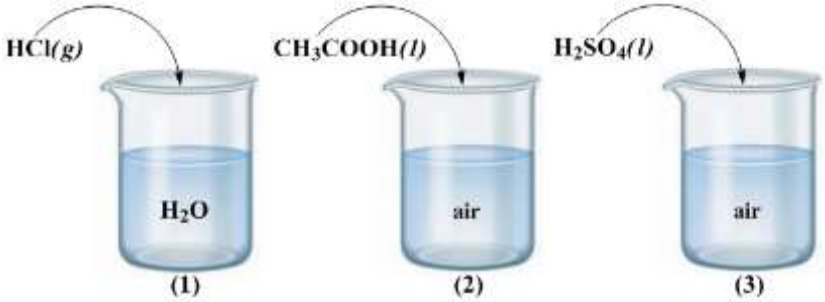



Fig. 4 A particular solution

(I) What components act as solvents? What components act as solutes?

(II) What happens when HCl, $CH_3COOH$, and $H_2SO_4$ substances was added into water?

(III) How does the reaction equation in each Beaker?

(IV) What is the similarity of reaction to each Beaker? Is there a similar reaction?

3. Concept Formation

   Metacognition at this stage is involved in the process of using comparisons and differences in cognitive characters in new concepts. The process of organizing acquired knowledge into new concept constructs is the conditional knowledge involved in the concept construction stage.Students with good conditional knowledge are able to place information at the exploration stage to form the definition of the Arrhenius acid concept.

   Simulation:

   Substances put into Beaker (1), (2), and (3) act as Arrhenius acid. So what is Arrhenius acid?

4. Application

   At this stage, metacognition have a role in the process of student reflection on new tasks, self-regulation of the whole process of acquiring new concepts, thinking about learning outcomes, and suggesting better alternatives or solutions to tasks as a form of students' cognitive readiness.The problems given at the application stage trigger the metacognitive knowledge of students simultaneously. Declarative knowledge is needed to know the relationship of microscopic images with the Arrhenius acid concept.Procedural knowledge is needed to interpret images and review reactions that occur based on the Arrhenius acid-base theory. Conditional knowledge is required to provide appropriate links and procedures so that the settlement step becomes effective.

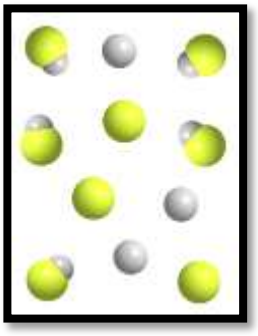
   Simulation:

   1. Given a solution of the following substances:

      (a) $HNO_3$ (b) HBr (c) $H_2SO_3$ (d) $H_3PO_4$ (e) HI (f) $HClO_4$

      Show the substances that include Arrhenius acid! Prove it by the equation of the reaction!

   2. Look at the microscopic image of the reaction in the following solution!



Note: the water solvent is not illustrated

HF $F^-$ $H^+$

Determine the Arrhenius acid species in the microscopic image!

5. Closure

   At this stage, metacognition appears in the process of monitoring understanding, the process of evaluating the achievement of learning objectives, and reflection on the use of strategies.Metacognition is also involved in the self-assessment process because students need to know the progress of their understanding, how well they can do the task, and the factors needed to improve performance.

   Simulation:

   (I) Limes, grapes, and tomatoes have the main content of citric acid ($C_4H_7O_5COOH$) and ascorbic acid ($C_5H_7O_4COOH$). Is there a reaction that causes the juice of these fruits have acid properties?

   (II) Give score and predicate your work on the application stage of each sub-topic!

**References**

Baird, J. R., & White, R. T. 1996. Metacognitive strategies in the classroom. *Improving teaching and learning in science and mathematics*, 190-200.

De Vos, W., & Pilot, A. 2001. Acids and bases in layers: The stratal structure of an ancient topic. *J. Chem. Educ*, *78*(4): 494.

Calatayud, M. L., Bárcenas, S. L., &Furió-Más, C. 2007. Surveying students' conceptual and procedural knowledge of acid–base behavior of substances. *J.*

*Chem. Educ*, *84*(10): 1717.Flavell, J. H. 1979. Metacognition and cognitive monitoring: A new area of cognitive–developmental inquiry. *American psychologist*, *34*(10): 906.

Drechsler, M., & Schmidt, H. J. 2005. Textbooks' and teachers' understanding of acid-base models used in chemistry teaching. *Chemistry Education Research and Practice*, *6*(1): 19-35.

Flavell, J. H. 1979. Metacognition and cognitive monitoring: A new area of cognitive–developmental inquiry. *American psychologist*, *34*(10): 906.

Händel, M., Artelt, C., &Weinert, S. 2013. Assessing metacognitive knowledge: Development and evaluation of a test instrument. *Journal for educational research online*, *5*(2): 162.

Hanson, D. M. 2005. Designing process-oriented guided-inquiry activities. *Faculty Guidebook-A Comprehensive Tool for Improving Faculty Performance. 2nd ed. Pacific Crest*.

Hanson, D. M. 2006. *Instructor's guide to process-oriented guided-inquiry learning*. Lisle, IL: Pacific Crest.

Karadan, M., & Hameed, A. 2016. Exploring the Features of Metacognition and Achievement Goals in Process Oriented Guided Inquiry Learning Instruction (POGIL). International Journal of Education and Psychological Research, 5(3): 39-43.

Kipnis, M., &Hofstein, A. 2008. The inquiry laboratory as a source for development of metacognitive skills. *International Journal of Science and Mathematics Education*, *6*(3): 601-627.Nakhleh, M. B. (1994). Student's Models of Matter in the Context of Acid-Base Chemistry. *J. Chem. Educ*, *71*(6), 495.

Nakhleh, M. B. (1994). Student's Models of Matter in the Context of Acid-Base Chemistry. *J. Chem. Educ*, *71*(6), 495.

Rickey, D., & Stacy, A. M. 2000. The role of metacognition in learning chemistry. *J. Chem. Educ*, *77*(7): 915.

Schraw, G., &Moshman, D. 1995. Metacognitive theories. *Educational psychology review*, *7*(4): 351-371.

Thomas, G. P., & Anderson, D. 2014. Changing the metacognitive orientation of a classroom environment to enhance students' metacognition regarding chemistry learning. *Learning Environments Research*, *17*(1): 139-155.

Veenman, M. V., Van Hout-Wolters, B. H., &Afflerbach, P. 2006. Metacognition and learning: Conceptual and methodological considerations. *Metacognition and learning*, *1*(1): 3-14.

White, B. Y., &Frederiksen, J. R. 1998. Inquiry, modeling, and metacognition: Making science accessible to all students. *Cognition and instruction*, *16*(1): 3-118.