

Development of POGIL (Process Oriented Guided Inquiry Learning) Strategy based on Intertextual Learning of Acid-Base Concepts

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Abstract –The aim of this study is to develop the POGIL (Process Oriented Guided Inquiry Learning) strategy of acids and bases concepts based on intertextual learning. The strategy was designed to assist students mastery concepts by interrelating the chemistry phenomena and acid-base concepts on three level representations: macroscopic, submicroscopic, and symbolic. The development process was initiating by curriculum analysis, developing three level representations of acid-base concepts, designing POGIL strategy intertextual-based, preparing instrument to measure students’s mastery concept, and POGIL application in a limited class. All instruments were judged by the experts (chemistry lecturers and teachers) in term of content validity. The results were considered valid by all validators with some improvements based on the validator’s suggestions and expertise.

Keywords—*Learning Strategy; Intertextual; POGIL; Acid-Base; Concept Mastery*

I. INTRODUCTION

Chemistry is one of the corner stone of science, technology, and industry that remarkably contributes to living existence, especially to improve life quality [1], therefore, it is essential to learn chemistry comprehensively. Previous works showed that students have many problems on learning of chemistry concept. Additionally, chemistry is still considered to be one of difficult subjects due to the abstract nature of many chemistry concepts, inappropriate learning strategy and method, and understanding deficiency of chemistry representations (macroscopic, microscopic, and symbolic) either on textbook or other learning sources. Those problems potentially led to student’s misconception [2-3].

On the other hand, acid-base theory is one of chemistry basic concepts since most of chemical reactions involve acid-base reactions [1]. Hence, it has been taught from primary level to the university [4-12]. Regarding to misconception phenomena on acid-base concept, Cross (1986) mentioned that around 47% and 14% of student’s misconception were found

for Bronsted-Lowry and Arrhenius theories, respectively. Additionally, Hawkes (in [11]) mentioned that students were confused on applying acid-base theories (either Arrhenius or Bronsted-Lowry) on problem solving of acid-based concepts, for example, on determination of acid-base definition and properties. In particular, student conception of acid-base was still dominated by Arrhenius theory, where merely that the substances produced OH⁻ and H⁺ ions in water are considered as bases and acid, respectively. In contrast, most students did not use the Bronsted-Lowry theory to explain the properties of acids and bases [4]. Those results inferred that students faced learning difficultness and may lead to misconception. Moreover, it is mentioned that there are two main sources of students’ misconceptions: (1) teaching process at school and (2) intuition that influenced by the representations or superficial meanings of characters and symbols of chemistry [12], suggesting that chemistry learning strategies play crucial role on creating student’s conception and/or misconception.

Meanwhile, intertextual in chemistry relates to interrelationship between chemistry phenomena and concepts by means of three level representations of chemistry i.e. macroscopic, submicroscopic, and symbolic level [13]. These representations can guide students to understand chemistry concept easily. Unfortunately, the application of three level representations on chemistry learning process was still infrequent.

At the same time, POGIL (Process Oriented Guided Inquiry Learning) learning strategy developed by Moog and Hanson was designed to assist students in enhancing their concept mastery [14]. According to Nadelson [15], POGIL based chemistry learning strategy can facilitate students to learn science freely even through the alternative conception. Furthermore, this method can support students on connecting the macroscopic and microscopic phenomena to symbolic representation. Hence, it is worthwhile to conduct a research study about the development of POGIL strategy based on intertextual learning for acid-base concept. This study is

conducted to the high school student which refers to the curriculum 2013 that implemented in Indonesia.

II. RESEARCH METHOD

This study was focused on development of POGIL strategy based on intertextual learning of acid-base, especially, Bronsted-Lowry theory. The development process was consisted of several stages i.e. (1) curriculum analysis to make the indicator of mastery concept, (2) analysis of acid-base concept from general chemistry textbooks to develop three representation levels of acid-base (i.e. macroscopic, submicroscopic, and symbolic), especially Bronsted-Lowry theory, (3) development of POGIL based on intertextual learning strategy (learning activities), (4) preparation of research instruments includes congruence tables of concept mastery indicators with basic competence of knowledge, concepts with the indicators of mastery concepts, learning activities with the POGIL strategies, and the aspect of mastery concept with learning activities, and 5) validation of instruments by the experts (chemistry lectures and teachers).

III. RESULTS AND DISCUSSION

According to the learning stages of POGIL, the early stages is orientation phase which provides the preliminary information of the subject that will be studied, the objectives as well as the learning outcomes. In this stage, the teacher provides some issues (phenomena) to encourage students motivation and interest on learning the subject. For example, here we serve the phenomena of cake dough expansion during baking process, where the baking powder (consist of sodium bicarbonate/ NaHCO_3 and sodium dihydrogen phosphate/ NaH_2PO_4) were dissociated as a result of heating. Since the cake dough contains water, it can be used as medium for NaHCO_3 and NaH_2PO_4 to be ionized become HCO_3^- and H_2PO_4^- ions, respectively. These ions will react to form HPO_4^{2-} and H_2CO_3 species. Hereafter, H_2CO_3 will be quickly dissociated to CO_2 and H_2O gases, consequently, expanding the cake dough volume. Indeed, the reaction between HCO_3^- and H_2PO_4^- ions can be classified as acid-base reaction. Moreover, in this stage, the teacher also guides students to remind the Arrhenius theory of acid-base which have been learned previously. Furthermore, students are given some questions, i.e. "Could you explain the acid-base reaction between HCO_3^- and H_2PO_4^- ions in term of Arrhenius theory?". This question triggered students to analyze the reactions that occur in HCO_3^- and H_2PO_4^- ions that can't be simply explained using Arrhenius theory, since there is no OH^- ion involved in the chemical formula. It was found the the students were confused and difficult to determine the base component from those ions. Therefore, teacher suggests that another concept (theory) is required to explain this reaction. Subsequently, students are asked to sit within the group that has been determined by the teacher randomly or heterogeneous (combination of upper and lower levels) where each group consists of three to four members. Based on the POGIL learning characteristics, each member within the group has different role play, where they can be either as manager, recorder, spokesperson, or analyzer strategy.

The next stage is exploration phase (includes observing, proposing and testing hypothesis, designing experiment-

includes designing the experimental step and identifying variables, and doing experiment). Each student acquires the worksheet about Brønsted-Lowry theory based acid-base concept. In particular, the worksheet contains focus questions i.e. "Why Ammonia (NH_3) solution is alkaline?". The objective of question is to make students easier to find out the concept about Brønsted-Lowry theory based acid-base, because the alkaline properties from ammonia solution can not be directly explained using Arrhenius theory. In this stage, some students demonstrate the experiment to determine the properties of ammonia and sodium hydroxide solution using acid-base indicators such as BTB (Bromtymol Blue) and the lytmus paper. The experimental result provides the clues for student to make a hypothesize (the answer to the focus question in the worksheet). The expected hypothesis that is "Ammonia solution is alkaline due to producing the OH^- ion" since this solution changed from colorless to blue after BTB addition, and the lytmus paper changed from red to blue. And then, some students are asked to check about the electrical conductivity in order to testing (confirm) their hypothesis. The electrical conductivity measurement demonstrates the ammonia solution is weak electrolyte since the lamp shows dim light and a few bubble around the electrodes can be observed. This means that few ions produced in this solution facilitate electron conduction in the outer circuit. The electrical properties of ammonia solution is a macroscopic representation of Brønsted-Lowry theory based acid-base. Furthermore, students observe the model 1 (Fig. 1) in order to find out the acid-base concept based on Bronsted-Lowry theory. The model 1 represents the symbolic level from the ionization of ammonia solution.

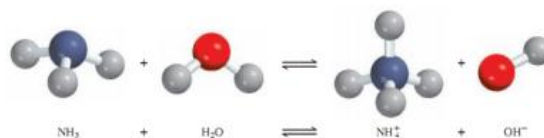


Fig. 1. The Model 1-Brønsted-Lowry Theory based Acid-Base Concept [16]

The next stage is the concept invention (formation phase), where the students are given some questions that require them to think critical and analytical on determination of acid-base components based on Brønsted-Lowry theory. Particularly, in the guided inquiry model, the learning activities are divided into several types based on the characteristic of POGIL questions (namely direct and convergent questions). The direct questions have an answer that only can be derived from the model. Through the given the direct questions, students are expected to be able to process the information presented in the model so they can answering questions related to the information and concepts to be learned. One of the example of direct questions is the changes in the H_2O molecules before and after reacting with NH_3 molecules, i.e., "Based on the observations, what ions are reduced from H_2O to become OH^- ? In addition, what ions are gained from NH_3 so it turns NH_4^+ ?", by providing that question, students are expected to answer that when H_2O turned into OH^- ion it releases H^+ ion and also when NH_3 turned into NH_4^+ ion it accepts H^+ ion.

Furthermore, students are also given some kind of convergent questions to enhance the concept of mastery in the formation of the understanding on Brønsted-Lowry theory

based acid-base concept. The convergent question is intended to assist students in making connections and getting a conclusion that cannot be obtained by direct question. One the example of convergent question is, "Why H₂O which is neutral is transformed into OH⁻ ion which has negatively charged? Instead why NH₃ is neutral turned into NH₄⁺ ions which has positively charged?". Based on these questions students are expected to answer that "H₂O turned into OH⁻ due to releasing the H⁺ ion while NH₃ turned into NH₄⁺ due to accepting H⁺ ion".

Next, students are given questions about the transfer of H⁺ ion occurs between H₂O molecules (acts as acid) and NH₃ molecules (acts as base). Through Model 1, students are expected to understand that the H⁺ ion moves from H₂O to NH₃, or from acid to base. And then, students are required to complete the hiatus question as a mean for students to make inferences from the concepts that have been learned. This statement also connects submicroscopic and symbolic representation levels of acid-base definition according to Brønsted-Lowry theory. The answer from the hiatus question actually gives a conclusion, where regarding to Brønsted-Lowry theory, acid is a particle that gives H⁺ ion to the base, while the base is a particle that receives H⁺ ion from the acid.

After forming the concept of Brønsted-Lowry acid-base, the next step is the formation of the concept of conjugate acid-base pairs through observations on the Model 2 (Fig.2).

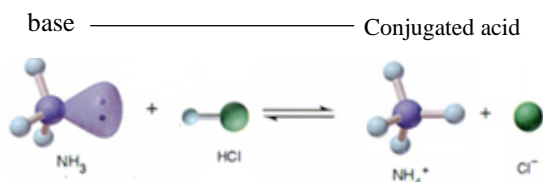
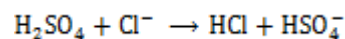


Fig. 2. Model 2-Acid Base Conjugate Pairs [17]

In the process of the concept formation, firstly, students must identify the acids and bases properties of all species exist in Model 2. Then, the students are given information of acid-base reaction that composed by two Brønsted-Lowry acid-base conjugate pairs (NH₃-NH₄⁺). Students are required to determine the other conjugate acid-base pairs in the reaction on model 2 (HCl and Cl⁻). Through this model, students are guided to create the definition of the conjugate acid-base pair.

The next stage is the strengthening and expansion of concept, namely the application phase (involves the use of new knowledge in the exercises/problem solving). Students are given the questions of the phenomenon that occurs in the dough expansion by mean of baking powder. Through this question the teacher helps students to relate the concepts with the phenomenon given in the beginning of learning activities and to realize that the studied concept is really close to daily activities and provides benefits for them. In addition to the some questions of concept applications, there is also a problem solving. In this case, the question was related to acid-base reaction without water solvent, for instance, the reaction of pure sulfuric acid with salt. Through this question, students are expected to apply the concept acid-base according to Brønsted-Lowry theory in order to answer that question.

Interestingly, some misconceptions were found in this term, for example, "the ionization of polyprotic weak acid (H_nX) is and is recognized as one step of the ionization reaction".



Finally, the last stage is the closing phase (reflection), where the students reflect on what they have learned and assess their performance by filling out their worksheet and doing self-assessment.

Moreover, the research instruments have high validity based on the experts (lecturers and teachers) judgement. Nevertheless, many comments and suggestions from the experts can be briefly summarized as follow:

- (1) The macroscopic representation level of Brønsted-Lowry theory based acid-base concept should be shown by the picture of white baking powder and the ingredient content.
- (2) The model 1 should not be labeled as acid and base. It is better to provide opportunity to students to independently discover (following inquiry approach) the properties of acids and bases of each species from the reaction of NH₃ and H₂O molecules. Based on this suggestions, the label acids and bases in the model 1 was removed.

The following questions are the revised version after correction by the experts.

1. Based on experimental results, what is the acidity of NH₃ solution?
 2. List the solute and solvent components of NH₃ solution.
 3. If it is known that the acidity properties are affected by the acidity the solute of the solution, then determine the acidity properties of the solute in NH₃ solution. (Write in the appropriate fields in the model 1)
 4. In Brønsted-Lowry theory based acid-base concept, if the solute is a base, then the solvent must be an acid. Vice versa, if the solute is an acid, then the solvent must be a base. What are the acidity properties of the solvent in NH₃ solution? (Write in the appropriate fields in the model 1)
- (1) It is better to provide the reaction equations in term of Lewis structure in order to facilitate students in determination of the ion charges. As well, the used of color variation for each species symbols will be helpful for students to easily distinguish which ions move from H.

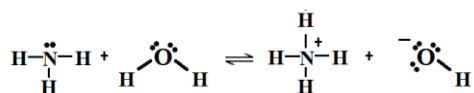


Fig. 3. Lewis Structure of NH₃ and H₂O reaction as Model 1.

- (2) Regarding to improvement of student thinking skill, the question of critical thinking was revised as follow:
 - a) How do the changes in NH₃ after reacting with H₂O?
 - b) What happened to the charge change in NH₃ after reacting with H₂O?
 - c) What particle causes NH₃ turn into NH₄⁺?
 - d) How do the changes in H₂O after reacting with NH₃?
 - e) What happened to the charge change in H₂O after reacting with NH₃?

- f) What particles are reduced, which causes H₂O turned into OH⁻?
- g) How many particles are reduced from H₂O thus changed into OH⁻ and how many particles are gained from NH₃ so it turns NH₄⁺?
- h) How is the transfer of particles that is occurred between NH₃ and H₂O molecules?
- i) Based on the input field in model 1, how the H⁺ ion transfer that is occurred between the acid and base particles?
- j) Based on the input field in model 1, according to the Brønsted-Lowry theory.
- k) Create the definition of acid and base according to the Brønsted-Lowry theory.

IV. CONCLUSIONS

Based on the results and discussion of development of POGIL strategy based on intertextual learning acid-base concept is derived the development of the worksheet and the design of learning activities using POGIL. The learning activities that have been developed in intertextual learning with POGIL strategy on acid-base concept involve the three representative levels of chemistry (macroscopic, submicroscopic and symbolic) into learning steps of POGIL.

Intertextual learning with POGIL strategy should be tested on students in the actual class to obtain student's mastery concepts and optimal improvement. Intertextual learning with POGIL strategy can be applied to other chemical concepts.

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