Solubility equilibrium learning supported by PhET-SS

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Abstract. Learning materials about solubility and solubility products tend to discuss the calculation aspects only. Therefore, it requires media able to describe the dissolution process in sub-microscopic and symbolic, namely using computer-based simulation. A learning using inquiry model supported by simulation media, PhET-SS, is required in order to make students capable of mastering the concept and to improve learning effectiveness in the classroom. This study aims to analyze the improvement of students' mastery on the concepts of solubility and solubility products after learning using inquiry model supported by PhET. The method used in this study is pre-experimental method with one group pre-test and post-test design. The subject of this study consists of 38 science students at senior high school. The research instrument used is in the form of mastery test on the concepts of solubility and solubility products. The result data is tested using N-Gain. The results show that the application of inquiry model supported by PhET-SS can improve the students’ mastery on the concepts of solubility and solubility products. It can be seen form the number of students experiencing increased mastery of the concept in high, medium and low category with average N-Gain in the medium one.

1. Introduction

Chemistry is one of the branches of Natural Sciences. Chemistry has several characteristics namely, it is a simplification of the truth, abstract, sequential and expanding rapidly. Solubility equilibrium is a part of chemistry that tends to deal with count. The presence of these characteristics makes students consider chemistry a difficult subject [1]. Due to students’ difficulties in understanding chemistry, teachers are required to be creative and innovative, for example by utilizing learning media [2]. Moreover, the increasingly evolving technology requires teachers to utilize technology in order to create and develop a learning media in accordance with its advancement [3].

It is the teacher’s job to select an appropriate learning model by integrating the learning strategies and media that will be used in the teaching-learning process [4]. The selected learning model should engage students actively in order to improve their conceptual mastery. Student-centered learning will involve the active participation of students in finding concepts, so as to achieve good conceptual mastery [5]. One of the learning models involving students’ activeness to find their own concept is inquiry model [6].
To solve this problem, one of the efforts possible is to use multimedia devices for learning process that can help students to do practicum though without real laboratory [7]. Multimedia is a digital product that presents and combines text, images, sounds, audios, and videos, which can be used by autodidact or students in the class [8]. Multimedia in the learning process has proven able to: create a fun learning atmosphere [9], enhance learning motivation, improve the effectiveness of learning [10], increase the understanding level [11], create student-centered learning, and enhance the investment efficiency of learning tools [12].

Virtual lab media such as PhET is one of learning media, which requires computer with java or flash program. One of PhET simulations on chemistry is Salts and Solubility (PhET SS), which describes the concept of solubility and solubility products [13]. A study about PhET simulations by [14] reveals the role of PhET in learning process that teachers may use virtual lab media, PhET-SS, to develop students’ ability to build concepts, but to develop a good science process skills, they are expected to provide students a direct learning experiences through real practicum activities.

Applying virtual lab media such as PhET in a learning process is expected to allow the material of salt solubility equilibrium to reach students’ long-term memory and eventually be able to improve their learning outcomes. According to explanation of the problems in the background, authors will conduct a research entitled “Solubility Equilibrium Learning Supported by PhET-SS”. This research to analyze the improvement of students’ conceptual mastery on solubility and solubility products through PhET simulation media using inquiry model.

2. Methodology
The method used in this study is pre-experimental method with one group pre-test and post-test design [15]. Sampling technique involves the whole class of third grade students of PGRI 3 Senior High School Bandung as many as 38 student. The instrument used in this research is concept mastering test. Types of data from this research consist of: 1) qualitative data, in the form of the explanation of student activity at each stage of inquiry model obtained from observers’ observation sheet, and 2) quantitative data, in the form of the percentage of student activity in learning process and the improvement value of student learning outcomes derived from the value of N-Gain pretest and posttest. The data of the research results are tested using N-Gain with the equation (1) [16].

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N - Gain = \frac{\text{skor posttes} - \text{skor pretest}}{\text{skor ideal} - \text{skor pretest}}
\]  

(1)

The procedure taken in conducting this research consists of three stages, namely the preparation stage, the implementation stage, and the final stage. The preparation stage includes analysis of any possible concept to build through PhET-SS, literature studies, design of learning strategies and research instruments, validation of research instruments, the selection of school and class to be the research place, and PhET-SS installation for learning process. The implementation stage includes written pretest, learning process supported by PhET-SS simulation, distribution of student worksheet, and posttest. The final stage includes the process and analysis of the data obtain, and the making of the conclusion.

3. Result and discussion
The learning process began with the first question, “What is a solution?” Some students correctly answered this apperception question, namely that a solution is a homogeneous mixture of two or more types of substances that form a single phase. The second questions were “What is an ionic compound? What if the ionic compound is dissolved in water? What is the ionisation equation of the ionic compound in water?”

Of all students there were only a few students who correctly answered these apperception questions, namely that an ionic compound is a chemical compound formed by the electrical charge held by each of its constituent atomic ions. Moreover, if an ionic compound is dissolved in water, it dissociates to form ions so that there is an electrically charged species. For example, NaCl with reaction: NaCl (s) →
Na\(^+\) (aq) + Cl\(^-\) (aq). The third questions were, "What is salt? What is the ionization reaction of salt in the water? ". Of all students there were only a few students who correctly answered these apperception questions, namely that salt is an ionic compound consisting of positive ions (cations) and negative ions (anions), thus forming a neutral compound (without charge). Moreover, the ionization reaction of salt in water is: NaCl (s) \(\rightarrow\) Na\(^+\) (aq) + Cl\(^-\) (aq).

Furthermore, the teacher gave a motivation aiming at arousing students’ curiosity by asking, "What will happen if the salt (soluble and insoluble) is dissolved in water? What if the process of dissolving salt in the water is continuously done? Will the salt continue to dissolve to form a salt solution? ". Students answered enthusiastically with various answers. Most students responded that when the salt is dissolved in water it will dissolve. Almost all students assumed that all types of salt will easily dissolve in water. From their answer, the teacher explained that, if soluble salt such as NaCl is added into the water, it will first dissolve. The more NaCl is added to the water, the more precipitate is obtained, called the saturated solution. If insoluble salt is added into the water, the solution will be saturated even if only a small amount of solute is added. If the process of dissolving salt in the water is continuously done, it will form a precipitate, called saturated solution, meaning that the solvent can no longer dissolve the salt.

In the next activity, the teacher distributed student worksheet about the simulation of the solubility of salt. NaCl, and students received their worksheet in groups. Then, the teacher guided and directed the students about how to operate the PhET-SS simulation and how to fill in the questions on the worksheets given. The teacher guided the students to formulate a problem based on the phenomenon-related question: "A student experiments to know what will happen if salt is dissolved into water. Then, the student dissolves 1 gram of NaCl into 1L water". The question presented in the worksheet is "what is the problem formulation appropriate to the experiment? (The problem formulation is made in the form of question) ".

The teacher then guided the students to do an experiment to prove the hypothesis with the following steps: Students ran PhET-SS, as shown in figure 1.

![Figure 1. “Table Salt” menu.](image-url)
According to figure 1, the teacher guided the students to click Run Now to start the simulation. Next, the students opened “Table Salt” menu. This Table Salt menu is the menu for the solubility of soluble salt. After they open table salt menu, they were guided to set the volume of solvent as presented in figure 2.

![Figure 2. How to set the volume of solvent.](image1)

![Figure 3. How to add table salt.](image2)
Figure 2 illustrates how to set the volume of solvent by setting the faucet in the bottom of the container to reduce the solvent and the one on top to add the solvent or in the data window on the right. Next, add a little amount of table salt as in figure 3. Figure 3 illustrates how to add table salt by shaking the display of the salt container. The table salt is continuously added until equilibrium is reached (there are deposited ions), as shown in figure 4.

![Figure 4](image)

**Figure 4.** The condition when equilibrium is reached.

Furthermore, the teacher guided the students to observe the phenomena in their experiment by filling the observation table consisting of: "particle movement (cations and anions), conclusions, and number of particles (cations, anions, total)". They analyzed their data, i.e.: "calculating the mole of the dissolved cations and anions, the total mole of cations and anions, and the concentration of the cations and anions as well as the concentration of the total cations and anions, and write it all in the table provided". Then, students developed the concept of solubility by the question presented: "On the addition of salt NaCl, is it true that there more the cations/anions are added, the more will be dissolved?". Given the question, the students are expected to be able to build the concept of solubility based on experimental simulations that have been done.

After finishing the learning supported by PhET-SS, the teacher guided the students to make conclusions based on the simulations by allowing the representatives of each group to read their conclusions in front of the class. The representatives who came forward presented the results of their worksheet and gave the conclusion of the learning quite well. However, the teacher eventually gave a reinforcement to the conclusions presented by them. Overall, the improvement of students' learning outcomes after learning process supported by PhET-SS obtained from the average values of pretest, posttest, and N-Gain is presented in Table 1.

| No | Description          | Pretest | Posttest | N-Gain |
|----|----------------------|---------|----------|--------|
| 1  | The average value of the class | 32,4    | 75,3     | 0,63   |
| 2  | Interpretation       | Less Good | Good     | Moderate |
Based on the data obtained, it can be seen that the conceptual mastery of all students improves with average value of N-Gain 0.63 and moderate category after the learning supported by PhET-SS on the material of salt solubility equilibrium. It is in line with the statement of [17] that the implication of PhET is very effective in improving student cognitive learning outcomes. It is also in accordance with a study by [18] that the use of inquiri model with PhET simulation media supports the student learning outcomes to increase. It is because PhET simulation makes learning process more attractive, with which the students can learn and play at once. The increased student cognitive learning outcomes are in accordance with the learning objectives that emphasize the process of finding and discovering. The materials for the lesson are given indirectly, the role of students in this strategy is to find and discover their own materials, while the teacher acts as a facilitator and supervisor to learn and to develop students’ ability to think systematically, logically, and critically, or develop intellectual ability as part of mental processes [19]. The details of the number of students who experience improvement in each improvement category of conceptual mastery based on achievement groups are presented in figure 5.

![Bar chart showing percentage of students in each improvement category.](image)

**Figure 5.** The percentage of the number of students in each improvement category.

Figure 5 shows that there are 9 students whose conceptual mastery improves with high category and percentage of 23.68%; 28 with moderate category and percentage of 73.68%; and 1 with low category and percentage of 2.63%. Based on the information obtained, it can be concluded that inquiry learning model supported by PhET-SS can improve students’ conceptual mastery.

4. Conclusion
Learning process of salt solubility equilibrium supported by PhET-SS can improve conceptual mastery of students included in high, moderate and low category with percentage of 23.68%, 73.68%, and 2.63% respectively.

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