Using PhET simulation to learning the concept of acid-base

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Abstract. This study aims to analyze student outcomes after learning the acid-base concept supported by PhET Simulation. The PhET simulation is used to help visualize sub-microscopic representation of the acid base solution. The method used is one group pre-test and post-test design with the subject this study consists of thirty high school students in the Bandung area. The research instrument used was a test that measured the ability to distinguish the strength of acid-base at the level of sub-microscopic representation, calculate the degree of ionization, the relationship of $K_a$ to concentration, and analyze the pH of the solution. The result of this study it can be concluded that the PhET simulation can improve student learning outcomes to the level sub-microscopic representation.

1. Introduction
Acid-base is one of the chemical concepts that includes several concepts including theory, definition, characteristics, strength, neutralization reaction, indicator and solution pH [1]. The concept of acid-base includes three levels of chemical representation, namely macroscopic, sub microscopic, and symbolic representations [2]. Reactions in acid or base solutions and characteristic strengths of acid-base involve proton transfer. The process that involves sub-microscopic level cannot be seen directly by students, even though the phenomenon that occurs can be observed using acid-base indicators [3]. There is a tendency for students to experience misconceptions regarding the strength of acid and base. Students assume, if a strong acid or base is diluted, it will become weak acid or base [4]. Solution pH is a measure of acid-base strength, not acidissty or basicity [5-7]. This is presumably because learning places more emphasis on understanding at the level of macroscopic and symbolic representation [8]. Understanding at the level of sub-microscopic representation is ignored. Various studies state students lack understanding the concept of acid-base, because learning does not use media that can link macroscopic phenomena that are observed through experiments with sub-microscopic representations involving the molecular level [9-11].

Therefore, one way to strengthen students' conceptions is to use computer-based media technology that is able to accommodate the need for abstract sub-microscopic level visualization. The learning process by applying science and technology will positively influence student achievement on student learning outcomes [12,13]. One of the android-based media is PhET (Physics Education Technology), which is a simulation media released by the University of Colorado [14]. Research using the PhET simulation as a learning medium has been carried out on the solubility equilibrium concept [15-17]. PhET simulation also provides PhET Acid-Base Solution (ABS) which is able to visualize the level of sub-microscopic representation of the acid-base concept. This paper describes how to use of PhET in chemistry learning and its impact on student understanding of the concept of acid-base.
2. Methods
The research method used by researchers is a pre-experimental design with one group pre-test and post-test [18]. This research was conducted at one secondary school in the Bandung area with 30 research subjects. Research subjects were grouped into three achievement groups based on the final chemistry test scores obtained. Three achievement groups are high, medium and low groups. Student understanding is measured using a written test. Written test compiled to measure four competency indicators, namely: 1) Measuring the ability to analyze the pH of strong / weak acids and strong / weak bases with the same concentration, 2) Describe the calculation of the degree of ionization of a solution known for the $K_a$ or $K_b$ value and its concentration, 3) Using the principle of the relationship between $K_a$ and the concentration and number of ionized H$^+$ ions, 4) Analyzing the difference in sub-microscopic representation between strong/weak acid solutions and strong/weak base solutions with the same concentration. The four competency indicators are taught to students using PhET simulations following the steps of scientific approach [19]. The research instrument used was a description of learning with a scientific approach, observation guidelines, student worksheets, and written tests.

3. Results and discussion
The learning process uses a scientific approach assisted by PhET simulations. For this reason, five stages of learning are carried out, namely observing, asking, collecting data, associating and drawing conclusions [20]. In the stage of observing, questioning and collecting data, students observe discourses and images related to acid-base phenomena and are asked to give questions that are relevant to the phenomenon. The purpose of the two stages is to arouse the curiosity of students, so that it makes them more interested in exploring further concepts. In the data collection stage, students conduct experiments measuring the pH of some acid-bases such as HCl, CH$_3$COOH, NaOH, NH$_4$OH solution which have the same concentration of 0.1 M; 0.01 M and 0.001 M. Furthermore, students connect the strength of acids or bases with the degree of ionization, the equilibrium constant of acid ($K_a$) and the basic equilibrium constant ($K_b$). At the association stage, students use PhET simulations so that students can understand how the different sub-microscopic representations of acid or base solutions are concentrated equally.

The following explains how the PhET Simulation is used in chemistry learning using a scientific approach. In the display of interface PhET acid base solution simulation there are two choices, namely "introduction" and "my solution". To understand the features of the display interface PhET simulations, students are asked to select the menu introduction. On the introduction menu there are several features, namely solutions, views and tools. The solution features available choices of solution, Water, Strong Acid, Weak Acid, Strong Base, and Weak Base. In the views feature there are Molecule, Graph, and Hide Views options. The tool features a choice of a pH meter, a universal indicator, and a light test kit. Display introduction can be seen in Figure 1. Once the basic features PhET simulations understood, then students select My Solution menu. Student Analysis of the pH of strong acid solutions, strong bases, weak acids, and strong bases with the same concentration was carried out using a pH meter and universal indicator. The ability of students to analyze sub-microscopic representations of various acid and base solutions having the same concentration is done by comparing each sub-microscopic representation seen in a PhET simulation.
Although the concentrations of strong acids / weak acids and strong bases / weak bases are the same, they can observe that each has a different pH solution. The difference is caused by the number of different concentrations of $H_3O^+$ or $OH^-$ ions depending on the value of the degree of ionization, $K_a$ or $K_b$ of the solution. The display of the relationship between sub-microscopic representation and the pH of the solution can be seen in Figure 2.

This strategy can improve the understanding of students who tend to assume that the pH of the solution indicates acid strength, not acidity. The use of PhET simulations accompanied by experiments can be a bridge between observations through real phenomena with molecular level visualization. The effect of experimental learning activities that are strengthened by the use of PhET simulations through a scientific approach can be seen from the results of the pre-test and post-test. Overall, there was an increase in students' understanding of the concept of acid and base. Improvement of students' cognitive learning outcomes for each group has a significant increase in achievement. The high achievement group gets an n-gain value of 0.8 with a high category, the medium achievement group gets an n-gain value of 0.8 with a high category, and the low achievement group gets an n-gain value of 0.6 with a medium category. While the average n-gain value for all achievement groups is 0.8 with a high category.

A common weakness of students in learning acid-base material is to distinguish between the concept of acid or base strength and the level of acidity or basicity [4]. By using a PhET simulation these problems can be overcome. For this reason, students are asked to observe and analyze the submicroscopic representations of strong acids, weak acids, strong bases and weak bases with the same concentration. Using the PhET simulation feature as illustrated in Figure 3, students can analyze the difference between acid strength (which is related to the value of K or degree of ionization) and acidity / basicity (which is related to the amount of Hydronium $H_3O^+$ ions or $OH^-$ hydroxide ions in solution).
Figure 3. Sub-microscopic representation: (a) strong acid 0.01M (b) Weak acid 0.01M (c) Strong base 0.01 M, (d) Weak Base 0.01 M.

The successful use of PHET simulations in learning can be seen from the improvement of students' abilities in the fourth learning indicator. The ability of students to analyze the pH of a weak acid solution as well as strong bases, strong acids, weak bases, the same concentration for each achievement group get an average n-gain value based on an average achievement group of 0.7 with a high predicate. The ability of students to analyze the differences in sub-microscopic representation for each achievement group is at an average value of n-gain of 0.8 with a high predicate.

Improved students' ability to analyze, allegedly influenced by practical learning activities strengthened by the use of simulated PhET. Besides, students get real experiences through direct observation of phenomena (levels of macroscopic representation), visually they can connect with levels of sub-microscopic representations [8,21]. This strategy can improve the understanding of students who tend to assume that the pH of the solution indicates acid strength, not acidity. The use of PhET simulation accompanied by practicum can be a bridge between observations through real phenomena with molecular level visualization. This is in line with Etikasari et al., acid and base learning using experiments can provide experience to students [22], so students can build concepts related to the material conducted during the experiment [23]. PhET simulations help students to have an atomic or particle level imagination [14,24]. Irwansyah et al., suggest that understanding sub-microscopic can be obtained through the use of computer and android technology that can visualize the sub-microscopic level [25]. The inclusion of visualizations and analogies of sub-microscopic forms in learning makes it easy for students to structure and the number of particles of a substance that cannot be directly observed by the eye [26,27].

4. Conclusion

Chemistry learning using PhET simulation can improve students' ability to analyze and relate macroscopic phenomena with sub-microscopic visualization. Students are able to distinguish sub-microscopic levels of strong acids / weak acids and strong bases / weak bases so as to avoid misconceptions.

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