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Enhancing Students' Conceptual Understanding of Chemistry in a SiMaYang Learning Environment

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Abstract.
Students' conceptual understanding of chemistry needs to be supported by the skill to think at three levels of representation. Many students have difficulty understanding chemistry concepts because of it. Chemistry teaching needs to provide a learning environment that involves chemical representations to facilitate students' interconnection skills of three levels of representation and ultimately improve students' conceptual understanding. SiMaYang learning was designed by integrating chemical representation during the learning process. This study aimed to enhance students' conceptual understanding of chemistry through the implementation of SiMaYang learning. A descriptive quantitative research method with one group pretest-posttest design was used in this study. Students' conceptual understanding was measured using three sets of essay tests containing macroscopic, symbolic, and submicroscopic tests for the topic of the buffer concept. The research data were analyzed descriptively and statistically using N-gain and paired sample t-tests. The results of the paired sample t-test showed the sig value. 0.000 <0.05, which means SiMaYang learning affects increasing students' conceptual understanding of chemistry. The finding of this study informed the students' conceptual understanding of chemistry increased in the medium category (N-gain = 0.62). SiMaYang learning, which was designed to involve three levels of representation, can increase students' conceptual understanding of chemistry.

Keywords: chemistry, conceptual understanding ,SiMaYang learning environment

1. INTRODUCTION

Buffer concept is one of the basic concepts that students must understand before studying advanced chemistry concepts. The buffer concept contains abstract concepts so that students often find it difficult to understand this topic. Several studies reported that many students have a low conceptual understanding of the buffer concept. Students often have difficulty understanding the context of the buffer concept, especially those related to applying concepts in life [1, 2]. Students also often fail to explain at particulate level how a buffer concept can maintain pH when added a little acid, base, or diluted [3]. Other studies also reported that students had difficulty understanding the buffer concept due to failure to interpret chemical symbols and formulas [2].

Students' difficulties in learning the buffer concept are related to the abstract concept characteristics of the topic. The learning environment that the teacher has designed tends to be less adapted to the characteristics of the abstract buffer concept. The buffer learning process is more about solving problems than studying concepts in depth. In the buffer learning process, students tend not to be accustomed to thinking abstractly to the particulate level in understanding concepts [3].

The strategy to overcome these student learning difficulties is designing a learning environment adapted to the characteristics of the buffer concept. The abstract character of the buffer concept can be represented at three levels of representation in chemistry. The macroscopic level is represented in the form of real phenomena in daily life that can be seen visibly and laboratory activities in pH measurement using a pH meter and universal indicators of the buffer. The submicroscopic level of buffer concept is represented in particulates such as dissociation of molecules and interactions between particles (ions and molecules) in preventing the pH of the solution. The symbolic level of buffer concept is represented in formulas or symbols, such as the writing of element symbol, the chemical reaction equation that occurs, and calculating the pH solutions. Based on it, designing a learning environment that involves explanations at three levels of representation is necessary.

Currently, there are not many buffer concept learning that involves the three levels of representation completely and does not involve the interconnection of the three levels [4]. Chemistry learning generally only involves the microscopic and symbolic levels. Learning in classrooms that are still dominated by macroscopic and symbolic levels can cause students difficulty to visualize structures and processes at the submicroscopic level to inhibit understanding of chemical concepts, and cause misconception [5, 6]. Meaningful learning in chemistry requires students' thinking skills simultaneously at the macroscopic, submicroscopic, and symbolic levels [7]. Therefore, learning needs to be designed by integrating chemical representations that can facilitate and support students in making connections between the three levels of representation [8–10]. Sunyono has developed a learning model that emphasizes the interconnection between the three levels of representation in chemistry called the SiMaYang model. The SiMaYang learning model is a learning model that emphasizes the interconnection of the three levels of representation, which consist of four stages: orientation, exploration-imagination, internalization, and evaluation. The stages of the developed learning model are arranged in the form of kites (Figure 1) and are named Si-5 Layang-layang or SiMaYang [11].

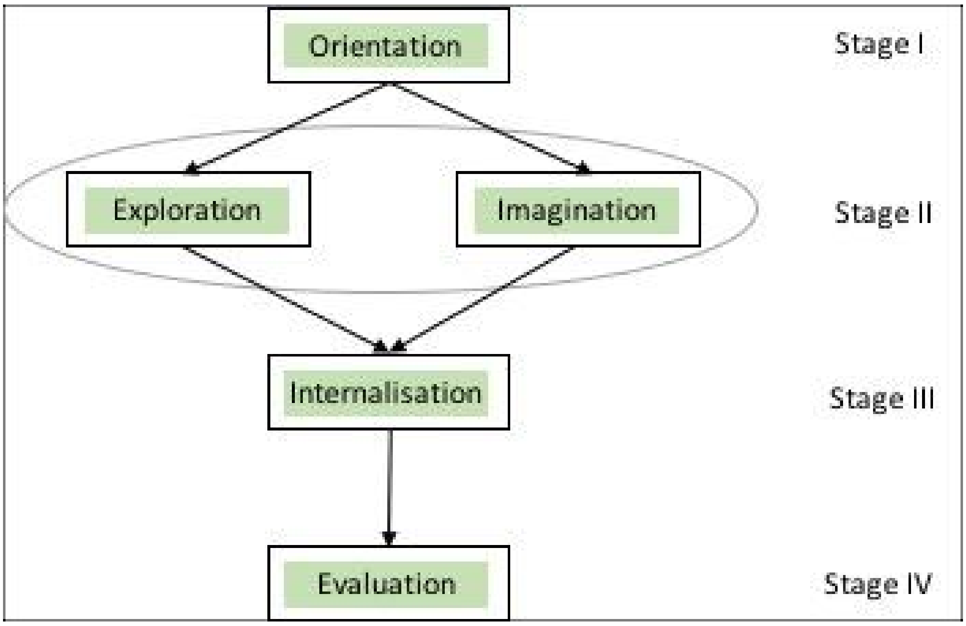

Figure 1: SiMaYang learning stages [11].

Previous research reported that the SiMaYang learning model effectively improves mental models and students' mastery of concepts [12, 13]. Some research on students' ability in translating between three levels of representation has also been carried out for some chemicals concepts, such as reaction rate [14], ionic reactions [15], chemical equilibrium [16], atomic structure [8], and acid-base titration [17]. This study is focused on implementing the SiMaYang learning model to determine its effect on the students' conceptual understanding reviewed from students' ability to connect three levels of representations in buffer concepts. Each stage in SiMaYang learning is designed creatively to facilitate students in making connections between the three levels of representation to improve students' conceptual understanding.

2. RESEARCH METHOD

This study was a descriptive quantitative study that used a pre-experimental method with One Group Pre-test Post-test Design. Participants in this study consisted of 30 students in one of the high schools in Serang-Banten, Indonesia. The participants were selected by purposive sampling. The selection of this sample was based on the consideration that the group of students has diverse abilities to provide representative information on the results of the study. This study begins with preparing research instruments and learning designs, followed by instrument validation and learning application. The SiMaYang learning in this study was designed by using microscopic videos and animations to stimulate the students' ability to connect the three levels of representations in explaining chemical phenomena. The SiMaYang learning environment was designed to improve students' conceptual understanding.

Students' conceptual understanding was measured using a test instrument consisting of three question packages (Table 1). Each problem package contains a buffer simulation in maintaining pH when a small amount of strong acid or strong base is added. Furthermore, students were asked to interpret and explain the experimental results (macroscopic level) into the reaction mechanism of the buffer in maintaining pH and calculated pH of the solution (symbolic level) and explanation at the particulate level of the buffer system process. The three test packages have been validated by two experts in the chemistry education field and tested in small groups, and the results are valid and reliable test packages.

Table 1: Explanation of three test packages.

Test packages	Explanation
1	NH_3/NH_4Cl buffer system experiment simulation
2	HCN/NaCN buffer system experiment simulation
3	the buffer system experiment simulation in the human body, H_2PO4^- /HPO_4^{2-}

Research data obtained through pretest and posttest. The research data were analyzed descriptively and statistically. Descriptive analysis was used to describe students' conceptual understanding of the buffer concept reviewed from the ability of students' three levels of representation. The enhancement of the students' conceptual understanding was analyzed by calculating the N-gain value from the pretest and posttest results. Then, the pretest and posttest data were analyzed statistically using paired sample t-test to know how the effect of the implementation of SiMaYang learning on increasing students' conceptual understanding.

3. RESULTS AND DISCUSSION

Three levels of representation (macroscopic, submicroscopic, and symbolic) in chemistry are needed in learning chemical concepts, one of which is a buffer concept. The ability to connect the three levels of representation determines how the students understand the chemicals concepts. This study implemented SiMaYang learning, whose characteristics of a learning environment involve the interconnection of three levels of representation, to improve students' conceptual understanding of the buffer concepts. The study results are in the form of learning outcomes data (pre-test and post-test), which represent students' conceptual understanding of buffer concepts (Table 2).

Table 2: N-Gain of students' interconnecting ability of multiple representation in chemistry.

Test Packages	N	Data Average		N-Gain	Category
		Pretest	Posttest		
1	30	15.29	71.97	0.67	Medium
2	30	2.41	65.75	0.65	Medium
3	30	1.32	56.20	0.56	Medium
Class Average		6.34	64.64	0.62	Medium

Table 3: The results of paired sample t-test.

t	df	Sig. (2-tailed)	Decision
-11.775	29	0.000	H_0 Rejected

The results in Table 2 show that after implementing SiMaYang learning, there was an increase in students' conceptual understanding of the buffer concepts (N-gain = 0.62). This result was supported by statistical test results using a paired-sample t-test. Based on paired sample t-test results obtained significance of $0.000 < 0.05$. It means that there was an influence of the SiMaYang learning model on improving the students' conceptual understanding of the buffer concepts. The increase in students' conceptual understanding simultaneously also increases students' ability to interconnect three levels of representation in explaining chemical phenomena. In this study, the students' conceptual understanding was analyzed from the students' ability to interconnect the three levels of representation in answering each test question.

There were differences in students' conceptual understanding before and after implementing SiMaYang learning. Before SiMaYang learning, students had difficulty understanding the buffer concepts. That condition can be observed from the students' answers results of the pretest that are wrong. Based on the analysis of students' pretest answers, it was known that students only provide answers in general from observations of simulated experiments. Example of student pretest answer: “addition of a little bit of strong acid, strong base or dilution does not change the pH of the buffer system significantly so that the pH can be maintained.” The answers were also accompanied by writing a wrong reaction equation, and some students did not write the reaction equation. Students still had difficulty calculating the pH value of the solution after adding strong acids or strong bases. Students do not understand how to describe the behavior of particles in a buffer solution in maintaining the pH solution when adding a little bit of strong acid or base. At the beginning of the study, most students showed difficulties in interconnecting between three levels of representation in chemistry: macroscopic, submicroscopic, and symbolic in problem-solving of chemistry [18]. Students’ difficulties can be caused by rarely practicing interpretation and interconnection of chemical representations such as submicroscopic level during chemistry learning. When students are given questions about submicroscopic images, they feel unfamiliar with the submicroscopic representation [14]. Chemistry learning in secondary schools less provided concrete examples either directly or visually about chemical concepts, and students were only given theoretical and verbal information without involving submicroscopic level explanations.

SiMaYang learning that has been applied three times has a positive impact on the students’ conceptual understanding and students’ ability to interconnect three levels of representation. SiMaYang learning provides a learning environment that stimulates students to learn chemical concepts more easily because it involves interconnecting three levels of representation. Students trained using submicroscopic representations could interpret the submicroscopic structure more easily, so that students’ knowledge of chemical representation and students’ interconnection ability of three levels of representations will increase [19]. Its condition was indicated by the students’ post-test answers that were more right and specific. Students can respond to observations of simulated experiments appropriately, accompanied by correct reaction equations. One example of student answers: “The buffer system of NH_3/NH_4Cl can maintain its pH when slightly alkaline (NaOH) was added by shifting the NH_3 equilibrium to the left as a result of OH^- (ionization result of NaOH) reacts with NH_4^+ and forms NH_3; NH_3 (aq) + H_2O (l) ⇔ NH_4^+ (aq)) + OH^- (aq). This condition caused increasing the amount of NH_3 and decreasing of NH_4^+ but not significantly, and the amount of OH^- ions in the solution remains so that the pH could be maintained”. That answer was supported by depicting the submicroscopic level of species contained in the buffer system appropriately. Students were able to describe the submicroscopic level of how the behavior of the particles in the buffer system maintained the pH of the solution. The number and the orientation directions of the particles were also described precisely. Besides, students were also able to prove that the pH of the solution does not change significantly through calculations. Three levels of chemical representation help students get an easy, complete, and meaningful understanding of concepts.

The SiMaYang learning model is proven to provide a learning environment that facilitates students to develop their conceptual understanding better [11–13, 19–21]. In this study, SiMaYang learning was designed by providing a learning environment that can facilitate students using three levels of representation in learning the buffer concepts. The learning environment was designed by giving students stimulus in natural phenomena related to the buffer concept verbally and visually through demonstration and visualizations such as pictures, simulations, microscopic animations, and analogies. Modeling as a picture, animation, simulation, experimentation, and demonstration are the appropriate strategies to teach chemical concepts at three levels of representation because they can make abstract concepts into concrete [22–24]. The use of video animations and animated images can also encourage students' interest in learning, increasing students' activity and enthusiasm for learning [5].

During SiMaYang learning activities, students are invited to think, develop creativity, and express their opinions at each stage of the learning, starting from the orientation, imagination-exploration, internalization, and evaluation stages. In the exploration-imagination stage, students are encouraged to use their imagination dan explore their knowledge through learning resources so that students can enhance their chemical representation ability as outlined in learning outcomes [5]. At the internalization stage of SiMaYang learning, students are allowed to communicate the results of their thinking through class presentations so that interaction activities are created, such as conveying, explain, and responding to the discussions' results students. In chemistry learning, the students' ability to connect the three levels of representation needs to be supported by explaining, justify, and argue [25].

The implementation of SiMaYang learning positively impacts students' conceptual understanding of the buffer concepts. The students' conceptual understanding of chemistry increased by a moderate category (N-gain = 0.62). Enhancement of the students' conceptual understanding in the medium category indicates that students need more to be trained using three levels of representation in learning chemical concepts. The teachers have to design a learning environment that can more facilitate students using three levels of representation during chemistry learning. The teachers need to choose and involve multiple representations and adopt several visualization approaches in supporting students learning chemical phenomena [26]. A chemistry learning environment that integrates multiple representations can support students in making connections between the three levels of representation and make learning more meaningful [8–10, 17, 24]. Thus, the students' ability to interconnect three levels of representation will increase, and students will find it easier to understand chemical concepts.

4. CONCLUSION

SiMaYang learning is proven to positively impact students' conceptual understanding of the buffer concept with a medium category (N-gain = 0.62). SiMaYang learning provides a learning environment that can encourage students to think, develop creativity, interpret and connect the three levels of representation in learning chemical concepts. A learning environment that involves thinking skills at three levels of representation can also help students understand chemical concepts more easily and completely. Students can explain well the buffer concept and interpret various phenomena involving three levels of representation. Based on this research, it is recommended to use SiMaYang learning in teaching chemical concepts. SiMaYang learning should be designed by providing simulations through pictures, animations, and also laboratory activities. SiMaYang learning design that involves laboratory activities accompanied by stimulus using dynamic animation media and computerized systems for submicroscopic level explanations will be interesting for future studies.

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