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Dynamic and Static Modeling Embedded in Inquiry Learning to Improve Student's Multiple Representation Ability

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Abstract

Integration of dynamic and static modeling on guided inquiry learning can help students to understand chemical concepts at macroscopic, symbolic and microscopic levels. This research aimed to examine and to explain the differences of students' multiple representation ability that was taught by guided inquiry with dynamic and static modeling in redox reaction concept. This research used descriptive and quasi-experimental design. Data were analyzed using descriptive and manova statistics analysis. The results showed that the ability of students' macroscopic level that was taught by guided inquiry with dynamic and static modeling is the same. While the student's symbolic and microscopic level ability that was taught by guided inquiry with dynamic modeling higher than student's ability that was taught by guided inquiry with static modeling. The implication of this research is chemistry learning with dynamic modeling can help students to construct chemical concept more easily and gain the complete understanding.

Keywords: Dynamic Modeling, Static Modeling, Guided Inquiry, Ability of Multiple Representation

INTRODUCTION

A full understanding of chemistry demands students to understand three levels of representation (macroscopic, symbolic, and microscopic) as well as the chemists use it to describe and explain chemical phenomena. Macroscopic representation is a concrete level that describes the real observations of chemical phenomena, including chemical phenomena occur in daily life (such as: discoloration, pH of solution changes, formation of gases and formation of precipitate in chemical reactions). Symbolic representation involves using of symbols of abstract objects so that easy to be understood. The symbolic representation involves reaction equations, mathematical equations, graphs, reaction mechanisms and analogies. Microscopic representation is abstract level that describes chemical processes which related with interaction of atoms, molecules and ions (Johnstone, 1982 in Chandrasegaran, *et al*., 2007). The three levels of representation complete each other in explaining of chemical phenomena. Explanations of chemical phenomena will not be understood well if it only use one or two levels of representation. Using of three levels of representation in chemistry learning is very important because it can help students to learn chemistry more fully and remember chemical concepts more easily (Tuysuz, *et al*., 2011).

The three levels of representation are also needed in learning redox reaction because it involves concrete and abstract concepts. Generally, learning of redox reactions concepts in schools only involves macroscopic and symbolic levels, whereas microscopic levels tend to be ignored. The condition causes students difficulty in learning of redox reaction at the microscopic level. Based on the research of Rosenthal & Sanger (2012), there are found students misconceptions in redox reaction such as incorrect predicting of ion charge in solution, cations and anions are attached or bonded together as ion pairs in water, not recognizing that a transfer of electrons changes the charges and sizes of the metal atoms or ions, and difficulty connecting the color of solution with the ions in it.

Based on these empirical studies, we need the appropriate strategies to teach the concept of redox reactions. One of them is the integration of microscopic modeling such as drawing and animation on guided inquiry learning. Tuysuz, *et al*. (2011) mention that microscopic modeling (images, animations), experiments and demonstrations are strategy which can make abstract concepts become concrete so that it produce a meaningful learning. In addition, animation, simulation and static visual are learning media and the appropriate strategy to teach chemistry concepts at the three levels of representation (Hilton & Nichols, 2011). While guided inquiry learning is a learning model that can train science process skills of students by giving chance to them to discover concepts independently through experiments and cooperative discussions so that they can develop their conceptual understanding. The results of a study reported that inquiry can improve students conceptual understanding, students achievement, science process skills, students ability to construct knowledge, make learning more meaningful because the concept can be stored in students long term memory and it can improve scientific communication skills (Tuan, et al, 2005; Yousefzadeh, *et al*, 2007; Blanchard, *et al*, 2010).

The innovation of inquiry learning with microscopic modeling such as computer-based visualization have a significant potential to improve students' conceptual understanding and achievement in chemistry (Linn, *et al*., 2006 in Stieff, 2011). Microscopic modeling can be static images and dynamic modeling such as animated video. Dynamic modeling and static images will give different effects on ability of students' macroscopic, symbolic and microscopic. In this study, has been done integration of dynamic versus static modeling in guided inquiry learning to help students construct the concepts of redox reactions at three levels of representation. Dynamic modeling is animated video about macroscopic phenomena of chemical concept followed by microscopic and symbolic explanation. While the static modeling is given in the form of power point slide containing macroscopic images of chemical concepts followed by microscopic and symbolic images without motion. An example of microscopic modeling in an animated video dynamic modeling is given in Figure 1.

Guided inquiry learning activity with dynamic and static modeling is designed based on three main activities of inquiry learning with visual media that is proposed by Stieff (2011) combined with the guided inquiry stages that is proposed by Hanson (2005). Stieff's inquiry learning activities that are *laboratory activity; simulation activity;* and *discussion activity*, whereas Hanson's guided inquiry stages that are orientation, exploration, concept formation, application, and closure. The steps of guided inquiry learning with dynamic and static modeling is presented in Table 1.

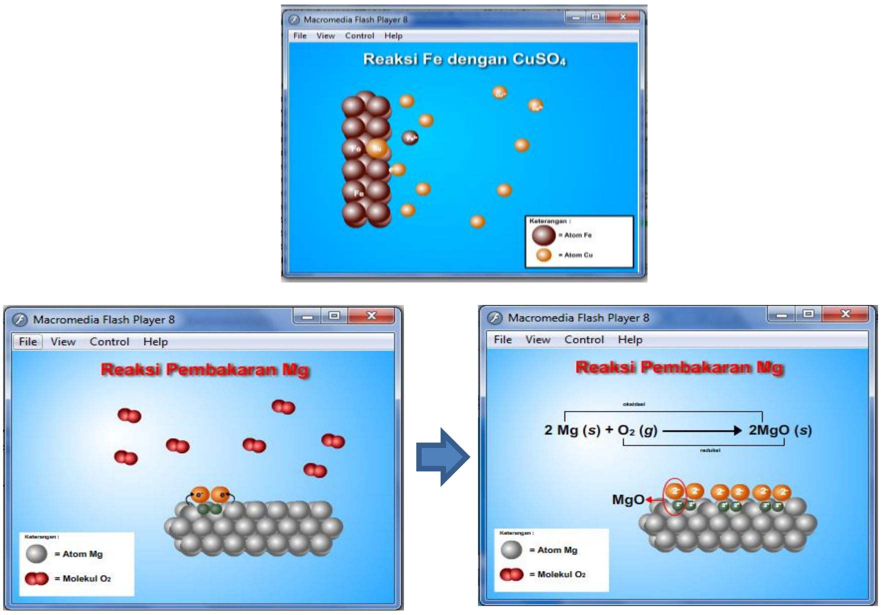

Figure 1. Example of Microscopic Modeling on Animated Video (Dynamic Modeling)

Table 1. Stages of Guided Inquiry Learning with Dynamic and Static Modeling

Stages	Explanation
Orientation	Prepare students to learn, motivate students, create interest, arouse curiosity, and explore initial knowledge. This stage is done by giving questions that are digging, focusing and guiding students on the material to be studied.
Exploration ➢ Laboratory Activity	At this stage students convey ideas, design experiments, do experiments in the laboratory, and make observations to collect data that will be used in problem solving. In this stage, students will get data of macroscopic images related with the issues studied.
➢ Simulation Activity	In the simulation activity, students explore microscopic media (dynamic/static modeling) to build microscopic ability of macroscopic phenomena that is obtained from experiments. Students are guided to make predictions and explanations about the relationship between macroscopic and microscopic levels.
Discussion Activity	This stage is the stage of concept formation. In this stage, students exchange information, share and clarify ideas, give and receive help and feedback. This process is designed to provide questions that encourage students to think critically and analytically related to macroscopic and microscopic exploration results. In this activity, students use multiple representation in transforming, analyzing, and interpreting data, and using it to create explanations, arguments, and conclusions.
Application	At this stage, students' knowledge and understanding are tested by giving a quiz in the end of each meeting and a test of learning outcomes in the end of the material
Closure	This stage is the final activity which students validate their learning outcomes, reflect what they have learned, and assess their performance (self-assessment). Validation is done by reporting learning outcomes (what they understand) to colleagues and teacher to gain perspective on the content and quality of learning outcomes

Guided inquiry learning activities with dynamic and static modeling is designed as in Table 1 aims to support and help students to integrate observation in the laboratory with microscopic and symbolic representation so that obtained a complete understanding.

METHOD

The participants of this research are students in first year at senior high school in Malang city. This research used descriptive and quasi experiment method that involve two groups of subjects (dynamic and static groups) with pretest-posttest design. Descriptive method was used to describe macroscopic, symbolic, and microscopic ability of redox reactions. Quasi experimental method was used to test the effect of dynamic and static modeling on guided inquiry learning to ability of students' macroscopic, symbolic and microscopic. The dynamic group is a group of students that was taught by guided inquiry learning with the dynamic modeling, and the static group is a group of students that was taught by guided inquiry learning with static modeling.

The ability of students' representation are measured using test instrument consisting of a macroscopic test, followed by symbolic and microscopic tests. The macroscopic test is description test about conclusion of the observation result from laboratory activity of redox reaction. In this test, students were asked to write it on the observation data sheet. The laboratory activity of redox reaction test consists of; 1) reaction of Zn with 2M $CuSO_4$ solution; 2) reaction of 3% H_2O_2 with 0.1 M NaI in acidic solution; and 3) reaction of 0.01 M $KMnO_4$ with a 0.1 M KI in basic solution. The symbolic test is description test containing writing the equation of redox reaction, determination of oxidation number and determination of oxidizing and reducing agents based on experimental results. The microscopic test is multiple choice test with the reason contaning of microscopic representation of solution in reactant, process of electron transfer and microscopic representation of solution in product. Pretest and posttest data were analyzed descriptively and statistically by using manova test. Increasing of ability of students multiple representation determined by calculating the N-gain (Normalized Gain) pretest and posttest. Normalized Gain (N-gain) and criteria show in Table 2.

Table 2. Decision Making Criteria of N-Gain

Criteria	Predicate
$Ng \geq 0.7$	High
$0.3 \leq Ng < 0.7$	Moderate
$Ng < 0.3$	Low

(Hake, 1998)

RESULTS AND DISCUSSION

The result of manova analysis on *tests of between-subjects effects* at significance level 0.05 obtained sig. value of macroscopic, symbolic and microscopic ability are 0.057, 0.016 and 0.000. The sig. value of students' macroscopic ability is 0.057 > 0.05, there is no difference in students macroscopic ability of dynamic and static class. While the sig. value of students' symbolic and microscopic ability is less than 0.05, that is the students' symbolic and microscopic ability of dynamic and static class are different.

The students' macroscopic ability is analyzed based on the students' ability to conclude the results of redox reaction experiment correctly and completely. Its criteria are correct in determining the oxidized species, the reduced species, the oxidation species and the reduction species. Data of pretest, posttest and N-gain of student's macroscopic ability both dynamic and static classes are given in Table 3. According to Table 3, students' macroscopic ability in giving conclusions of redox reaction correctly and completely both dynamic and static classes has increased on moderate criterion with the everage N-gain value 0.4 for students dynamic class and 0.3 for students static class.

Determination of the four species in redox reaction are based on change of ionic type in solution that are indicated with the color change and the formation of precipitate. According to the analysis of students' answers, it was found that students who were correct in determining the type of ions formed in solution and the type of precipitate, they were mostly correct in giving conclusions, while the students who were wrong in determining the type of ions formed in solution and the type of precipitate, they were mostly wrong in giving conclusions.

The students' symbolic ability is analyzed based on the students' ability to write the redox reactions equation, determining the oxidation number and determining oxidizing and reducing agents. The improvement of students' ability to integrate the macroscopic observation to symbolic levels are given in Figure 2.

The student's symbolic ablity in writing redox reaction equation of experimental result is based on the student's ability to write redox reaction equation correctly and completely, i.e. correct in writing the oxidation reaction (substance, phase, position and number of electrons); reduction reaction (substance, phase, position and number of electrons) and the overall of redox reactions. Figur 2 shows that students' symbolic ability in writing redox reaction equation for dynamic classes has increased on moderate criterion, while the students' symbolic ability of static class is still low

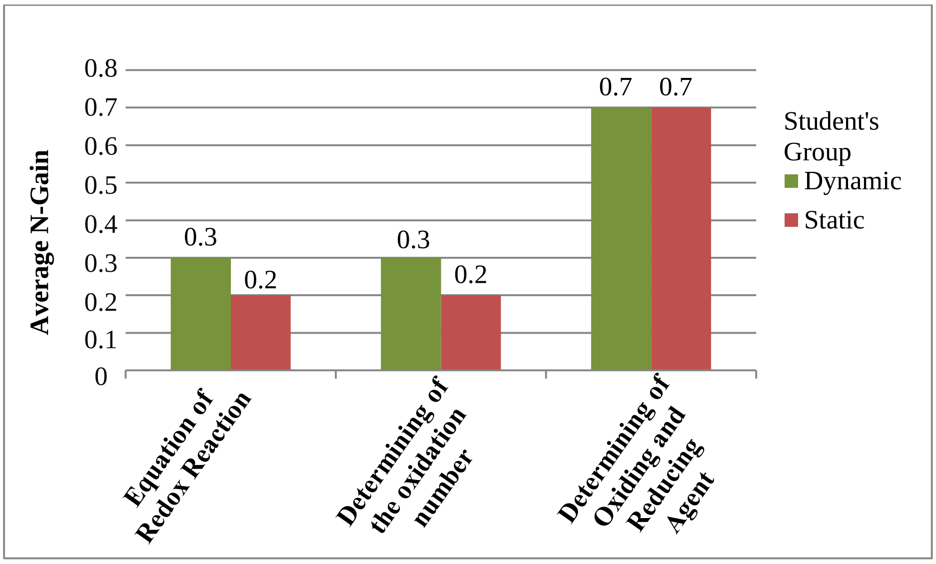

Figure 2. The Graphic of the Improvement of Student's Ability to Integrate the Macroscopic Observation to Symbolic Level

Table 3. Data of Pretest, Postest and N-gain of Students Macroscopic Ability

Aspects Studied	**Dynamic Class**			**Static Class**		
	Pretest (%)	**Posttest (%)**	**N-Gain**	**Pretest (%)**	**Posttest (%)**	**N-Gain**
Conclutions of the result of redox reaction experiment						
Redox Reaction in Neutral Solution	0.0	67.6	0.7	0.0	39.5	0.4
Redox Reaction in acidic Solution	0.0	27.0	0.3	0.0	34.2	0.3
Redox Reaction in basic Solution	0.0	35.1	0.4	0.0	28.9	0.3
Average	0.0	43.2	0.4	0.0	34.2	0.3

According to the analysis of students' answers, students' errors in writing redox reaction equation incomplete or wrong, i.e., 1) incorrect in writing the oxidation reduction product, 2) incorrect in writing the phase of substance, 3) incorrect in writing the position and number of electrons, 4) incorrect in equalizing the redox reactions, mainly redox reactions in acidic and basic solution, 5) incorrect in writing overall of redox reaction. The error in equalizing the redox reaction is the most errors in the student's answer.

The students' symbolic ability in determining the oxidation number of atoms is analyzed based on the student's ability to determine the oxidation numbers of all the atoms involved in the redox reaction correctly and completely. According to Figur 2, the ability of dynamic class students to determine the oxidation numbers of all atoms involved in redox reactions has increased on moderate criterion with the N-gain value of 0.3, while the ability of ststic class students are still low with the N-gain value of 0.2. Based on the analysis of students' answers, it is known that the low level of students' symbolic ability in determining the oxidation number of atoms is because of students have not been able to determine the oxidation number of atoms fully, where the oxidation numbers of several atoms can be determined correctly while for the oxidation number of some other atoms still wrong. This indicates that the students do not understand the rules of determining the oxidation number well.

The students' symbolic ability in determining the oxidizing and reducing agents is analyzed based on the students' ability to determine both oxidizing and reducing agent correctly. According to Figur 2, the students' symbolic ability of dynamic and static class in determining the oxidizing and reducing agents increased on high criterion with an average N-gain value of 0.7.

The student's microscopic ability of redox reactions is analyzed based on the students' ability to determine the microscopic representation of solution in reactant, process of electron transfer and microscopic representation of solution in product with the correct reason. The improvement of students' ability to integrate the macroscopic dan symbolic level to microscopic level are given in Figure 3.

According to Figure 3, the students' microscopic ability of both dynamic and static classes in giving microscopic representation of solution in reactant increased on high criterion with the N-gain value of 0.8 for dynamic class and 0.7 for static class. Moreover, the students' microscopic ability of dynamic class in giving microscopic representation of electron transfer process and microscopic representation of solution in product increased on medium criterion with the N-gain value of 0.5, while students ability of static class are still low. Its results show that students of dynamic class have been able to transfer and connect the macroscopic and symbolic representation of redox reactions into microscopic explanation.

Whereas, the low level of students symbolic abiliy of static class in giving microscopic represntation of electron transfer process and solutions in product indicated that students static class should practice a lot in transferring the macroscopic and symbolic representation into microscopic level. According to the analysis of students' answers, generally the most of students have been able to determine the microscopic representation of redox reactions correctly, but they are still wrong in giving reasons for the selected microscopic picture.

Data analysis above shows that after learning, students of both dynamic and static classes increased macroscopic, symbolic and microscopic ability. This suggests that intergration of dynamic and static modeling in guided inquiry learning has a positive effect on ability of students' macroscopic, symbolic and microscopic. Using of dynamic and static modeling on guided inquiry learning can present the chemical concept at the macroscopic, symbolic and molecular (microscopic) level so that students can understand the redox reactions concept easily. Integration of microscopic media in describing chemical processes can improve students' conceptual ability at the macroscopic, symbolic, and microscopic levels (Kelly, *et al*, 2004).

Dynamic and static modeling are media that can help students to construct chemical concepts more easily. The integration of dynamic and static modeling on guided inquiry learning gives the same effect to ability of students' macroscopic in redox reaction. This is because both classes are taught by the same learning model that is guided inquiry that involves experiments in the laboratory. The macroscopic picture of chemical phenomena is obtained by students of both classes through laboratory activity.

The integration of dynamic and static modeling on guided inquiry learning gives the different effect to ability of students' symbolic and microscopic in redox reaction. According to research results, the symbolic and microscopic ability of student's dynamic class tend to be better than the static class students. It is because of the dynamic modeling gives the representation of chemical concepts more clear than the static modeling. In addition, the dynamic animation is more effective in improving the student's conceptual ability than static images (Antonoglou's, *et al.*, 2006; Tasker & Dalton, 2006; Yarden & Yarden, 2009; Dori & Kaberman, 2012).

The superiority of dynamic modeling than the static modeling is the presence of motion in dynamic modeling so that the description of macroscopic, symbolic and microscopic phenomena becomes clearer and easier to understand. According to Sanger & Greenbowe (1997), the static images do not provide enough information in helping students to understand the dynamic nature of chemical reactions such as electron movements, discoloration during chemical reactions and atomic positions in molecules. While, dynamic animation provides dynamic information about exchange of electrons between ions and atoms, molecular structure, particle movement and other chemical reactions at the microscopic level (Liu, *et al*., 2008) so that it make the learning more interactive and authentic and abstract concepts becomes more concrete (Ramasundarm, *et al*., 2005 in Smetana & Bell, 2012). Dynamic animation can also help students to build strong links between three levels of representation (macroscopic, symbolic, and microscopic) so that finally it can improve student's representation skills (Wu, *et al*., 2001; Ardac & Akaygun, 2004; Levy, 2013; Langitasari, 2016).

The results of this research proved that the integration of dynamic modeling on guided inquiry learning is a potential strategy to improve ability of students' macroscopic, symbolic and microscopic. Using of animation on inquiry approach is one of alternative strategies that can help students to understand abstract concepts (Zhang & Linn, 2011; Levy, 2013; Utari, *et al*, 2017). In addition, Stieff (2011) stated that guided inquiry learning with animation explains how microscopic interactions of chemical species can produce macroscopic observations and are represented with symbolic representations. The integration of animation on inquiry learning is very effective in helping students to improve conceptual ability in chemistry (Smetana & Bell, 2012). Furthermore, experiments are equipped with dynamic visual media give a more significant effect on students' ability at the molecular level (Chang & Linn, 2013). Therefore, dynamic modeling such as animated videos is more effectively in helping students to build ability of macroscopic, symbolic, and microscopic in chemistry.

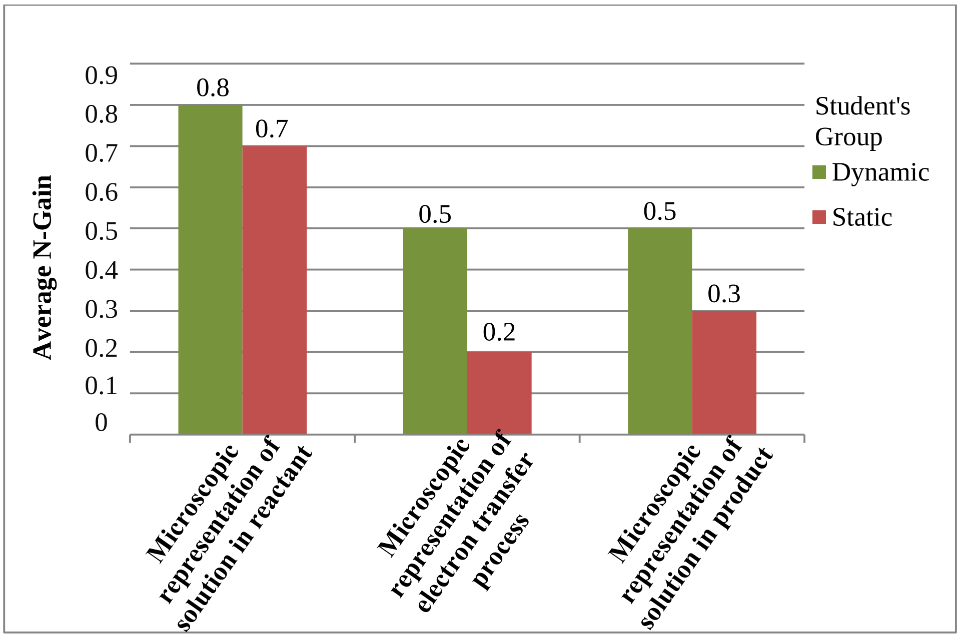

Figure 3. The Graphic of the Improvement of Student's Ability to Integrate the Macroscopic and Symbolic Level to Microscopic Level

CONCLUSION

The integration of dynamic and static modeling on guided inquiry learning can help students to develop ability of student's representation. The ability of students macroscopic that was taught by guided inquiry with dynamic and static modeling are the same.While, the ability of students symbolic and microscopic level that was taught by guided inquiry with dynamic modeling higher than student ability that was taught by guided inquiry with static modeling. Chemistry learning by involving dynamic modeling such as animations that present chemical processes and reactions at macroscopic, symbolic and microscopic levels can help students to construct chemical concepts more easily so that gain a complete understanding.

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