Learning nucleophilic substitution reaction based on 3D-visualization to improve students’ critical thinking ability

D N Adika*, Liliasari, and I Musthapa
Departemen Pendidikan Kimia, Universitas Pendidikan Indonesia, Jl. Dr. Setia Budhi No. 229, Bandung 40154, Indonesia
*dessinuradiska094@gmail.com

Abstract. The purpose of this study was to identify the effect of using 3D-visualization on learning nucleophilic substitution reaction to improve students' critical thinking ability. This study used quasi experimental pretest and postest design. This study involved 68 students from two different universities in West Java. University A have 37 students and university B have 31 students involved at the study. The critical thinking ability test instrument consists of 9 multiple choice questions with reasons. The results show that learning using 3D-visualization on nucleophilic substitution reaction can improve students’ critical thinking ability. Based on the N-gain result, students of the university A better than the university B, except on ‘identifying/formulating criteria to assess possible answers’ indicator of critical thinking ability. It should be increase students’ critical thinking skills especially in the university B through further effort.

1. Introduction
In this 21st century, students must have critical thinking ability to be able to analyze information from various sources and connect previous knowledge with new knowledge, to produce meaningful learning. Critical thinking ability can be built through discussion activities and answering questions during the learning process [1]. Critical thinking ability need to be developed by students because it is important to make great informed assessments, be able to explain reasons and be able to solve unknown problems [2]. Critical thinking consists of the ability to search sources of knowledge, test the validity of knowledge, questioning reliability, and make evaluations to reach conclusions [3].

The use of computer programs such as chemdraw applications can help lecturers to make students more involved in the learning process. Chemistry is a challenging topic for some students, because it requires mastery of abstract concepts that are important in understanding molecular structure, physical properties, and complex chemical transformations [4]. Integrating modelling tools such as chemdraw computerized programs can improve students’ ability to understand chemistry better [5]. The effect of learning with three-dimensional simulations compared to two-dimensional illustrations using computer programs with different versions can reduce cognitive load, so as supporting active learning [6].

In several research that has been done, the use of visualization can help students understand stereochemistry. However, the use of visualization media has not yet test species in transition to facilitate understanding structural determination in organic chemical reactions such as unimolecular and bimolecular nucleophilic substitution (S_N1 and S_N2) [7]. On the other side, integration studies of molecular modelling in order to create active learning but did not test the extent of understanding of chemical concepts produced by students [5]. This makes researchers interested in learning based on 3D-
visualization on the \( S_N2 \) and \( S_N1 \) reaction mechanism. Therefore, students not only understand the three-dimensional visualization form of a molecule, but are able to predict a compound through the \( S_N2 \) or \( S_N1 \) reaction mechanism and based on data the student is able to determine which C atom is more reactive in a reaction.

In this study, researchers integrated 3D-visualization media in teaching materials to help students predict a compound through the \( S_N2 \) or \( S_N1 \) reaction mechanism, so that by looking at the data contained in the media students do not need to memorize but are able to understand and connect between theories and data. Therefore, it is necessary to learn the mechanism of \( S_N2 \) and \( S_N1 \) reaction based on 3D-visualization to improve students’ critical thinking skills. The purpose of this study is to improve students’ the critical thinking skills on the concept of bimolecular (\( S_N2 \)) and unimolecular (\( S_N1 \)) nucleophilic substitution reactions mechanism.

2. Method

The research method used in this study is a quasi-experiment with pre-test and post-test design. This design was implemented in groups that were given treatment and groups were not randomly selected. The data to be processed is obtained from the results of the pre-test and post-test. This study involved 68 students from two different universities in the second semester in West Java. University A with 37 students and B with 31 students. Two groups of experimental samples were used to determine the effect of learning the students with different backgrounds. The study was conducted on three meeting. At the first meeting was given a pre-test for 1x50 minutes, the second meeting learning process is implemented by giving videos containing concept and how to use 3D-visualization media for 2x50 minutes, and the third meeting was given a post-test for 1x50 minutes. The critical thinking ability test instrument consists of 9 multiple choice questions with reasons. The maximum score for each question is 11, each question is given a score of 5.5 for the correct option and a score of 5.5 for the reason. The critical thinking indicator used is Ennis’s critical thinking consisting of identifying assumptions, defining terms, identifying or formulating criteria to assess possible answers, and analyzing arguments.

3. Result and Discussion

The results of the study consisted of data on students’ critical thinking skills measured using reasoned multiple choices test questions. The result is analyzed using normality test, homogeneity test, significance test, and \( \text{N}-\text{gain} \) are calculated.

3.1 Analysis of test result

Analysis of the test result using the normality, the homogeneity, and the significance test presented in Table 1.

| Data                  | N    | Average Score | Normality    | Homogeneity  | Significance Test               |
|-----------------------|------|---------------|--------------|--------------|---------------------------------|
| Pretest University A  | 37   | 71.65         | Normal       | Homogeneous  | \( H_0 \) rejected (significantly different) |
| Posttest University A | 31   | 82.77         | Not normal   |              |                                  |
| Pretest University B  | 31   | 35.19         | Normal       | Heterogeneous| \( H_0 \) rejected (significantly different) |
| Posttest University B | 51   | 51.39         | Normal       |              |                                  |

Prerequisite test results indicate that, normality test using Shapiro-Wilk because the number of samples is less than 50(N<50), with a significance level of \( \alpha = 0.05 \). University A the pre-test significance value was greater than \( \alpha = 0.05 \). This means that \( H_0 \) is accepted, then the data is normally distributed. While the post-test data is not normally distributed because the significance value of post-test is smaller than \( \alpha = 0.05 \). University B obtained a significance value of pre-test and post-test greater than \( \alpha = 0.05 \),
meaning that \( H_0 \) was accepted then the data were normally distributed. The homogeneity test show that university A the significance value is greater than 0.05, this means that the data group comes from a population that has the same variance (homogeneous). While university B has a significance value lower than 0.05, meaning that the data are not homogeneous. Statistical test used is non-parametric because at university A the pre-test data is normal and the post-test is not normal, while the data are homogeneous. University B pre-test and post-test data are normal but not homogeneous. So that, it does not meet the parametric test requirements and the Wilcoxon test is performed. The Wilcoxon test conclusions showed that for the universities A and B, \( H_0 \) were rejected because sig. <0.05. It means that there were significant differences between pre-test and post-test. So, learning nucleophilic substitution reaction based on 3D-visualization can improve critical thinking ability at both universities A and B.

3.2 N-gain/Normalized gain

N-gain is used to determine the difference between pre-test and post-test at both universities, using the following formula

\[
< g >= \frac{\text{score posttest} - \text{score pretest}}{\text{maximum score} - \text{score pretest}}
\]

The results of the N-gain value are presented in table 4 using the pre-test score, post-test score, and N-gain data for all critical thinking abilities indicators revealed through tests presented in table 2.

| University | N | Average Posttest | Average Pretest | Average N-Gain % | Conclusion |
|------------|---|-----------------|-----------------|-----------------|------------|
| A          | 37 | 82.77           | 71.65           | 41              | Medium     |
| B          | 31 | 51.39           | 35.19           | 25              | Low        |

Based on table 2 learning using 3D-visualization media can improve students' critical thinking skills, for university A at medium level and university B low level. This means that the improvement of critical thinking ability is better at university A than university B. In addition, university A obtained higher pretest scores than university B, this shows that students with better initial knowledge will easily understand the material. So that indicators of critical thinking skills will be easy to achieve. Students with better knowledge will find it easier to follow lessons that emphasize thinking skills because they have better term memory retention. The improvement of critical thinking skills shown from learning outcomes can be improved through the use of technology in learning by actively processing the information obtained from various sources [8]. Learning that is centered on student activities can practice critical thinking skills continuously through activities to identify problems and identify problem variables, so as to find steps to solve these problems [9]. In this study, the N-gain test of the indicator of critical thinking skills is also used consisting of four indicators presented in table 3.

Table 3 shows that, in the university A students get high category N-gain of identify assumptions and medium category on the other three indicators of critical thinking skills. On the other hand, university B only get medium N-gain of two indicators and low category on the other two critical thinking skills indicators. Overall, for each indicator, university A obtained a greater N-gain value than university B, except in ‘identifying/formulating criteria to assess possible answers’ critical thinking skills’ indicator on both universities get the same N-gain in medium category. It is ‘absolute configuration’ concept. The evidence can be explained that using Chemdraw software will make students improve their critical thinking ability [4,5]. Table 3 show the increase of critical thinking skills indicators.
Table 3. Increased Indicator of Critical Thinking Skills

| Indicator                              | Concept                          | Question | University A | University B |
|----------------------------------------|----------------------------------|----------|--------------|--------------|
| Identify assumptions                   | compounds polarity               | 1        | 73 High      | 56 Medium    |
| Defining terms                         | Steric effects, S\textsubscript{2} mechanism, carboxation, S\textsubscript{1} mechanism | 2.5.6.7.8 | 38 Medium    | 23 Low       |
| Identifying/formulating criteria to assess possible answers | Absolute configuration | 3        | 44 Medium    | 31 Medium    |
| Analyzing arguments                    | Stereo-isomer, S\textsubscript{1} and S\textsubscript{2} reaction mechanism | 4, 9     | 33 Medium    | 20 Low       |

For the concept ‘compound polarity’ students of university A get the high category of N-gain, but for students in university B they only get medium category. Data to answer problem in compound polarity concept is not in the 3D-visualization media but it is explained how to obtain the data on the material provided, it can be said that students’ critical thinking skills increase because they are able to analyze information from various available sources [1]. The concept of steric effects, stereo-isomers, carbo-cations, S\textsubscript{1} and S\textsubscript{2} reaction mechanisms, can be explained through modelling using 3D-visualization media that can support students’ critical thinking skills on indicators defining terms and analyzing arguments. These questions use the help of chemoffice to make it easier to understand and solve [2.4.5.6.7]. The concepts related to the spatial studied such as stereo-isomer can be explained with the help of interactive multimedia [10].

4. Conclusion
In this research, the learning of nucleophilic substitution based on 3D-visualization can improve students’ critical thinking skills in both university. Based on N-gain values, the students of university A get better improvement of critical thinking skills than students of university B, except on ‘identifying/formulating criteria to assess possible answers’ indicator of critical thinking skills. It is parallel with their concepts mastery in nucleophilic substitution using 3D-visualization media. Therefore it should be increase students’ critical thinking skills and concepts mastery, especially in the university B through further effort.

5. References
[1] Rahayu U & Sapriati A 2018 Open Educational Resources Based Online Tutorial Model for Developing Critical Thinking of Higher Distance Education Students Turkish Online Journal of Distance Education 19 4 163-175.
[2] Thomas T 2011 Developing First Year Students’ Critical Thinking Skills Asian social science 7 4 26.
[3] Linn M C 2000 Designing the Knowledge Integration Environment International Journal of Science Education, 22 781–796.
[4] Bharathy J B 2015 Importance of Computer Assisted Teaching & Learning Methods for Chemistry Science 3 4 11-16.

[5] Raiyn J & Rayan A 2015 How Chemicals’ Drawing and Modelling Improve Chemistry Teaching in Colleges of Education World Journal of Chemical Education 3 1 1-4.

[6] Uhrhane D Nick S & Schanze S 2009 The Effect of Three-Dimensional Simulations on The Understanding of Chemical Structures and Their Properties Research in science education 39 4 495-513.

[7] Setyarini M Liliasari L Kadaroehman A & Martoprawiro M A 2017 Effect of Stereochemical Learning Based on 3D Molecular Visualization to Improve Spatial Ability Cakrawala Pendidikan 1 91-101.

[8] Barak M Lipson A & Lerman S 2006 Wireless Laptop as Means For Promoting Active Learning in Large Lecture Hall Journal of Research and Technology in Education 38 3 245-263.

[9] Carind A A & Sund R B 1998 Teaching Science through Discovery (6th Edition) Ohio Meril Publishing Company.

[10] Sumarni W & Sudarmin S K 2013 Pembelajaran Berbasis Multimedia untuk Meningkatkan Penguasaan Konsep Kimia dan Keterampilan Berpikir Mahasiswa Jurnal Ilmu Pendidikan Universitas Negeri Malang 19 1 69-77.