Improving Chemistry Prospective Teacher's Conceptual Understanding of Resonance Using Multiple Representations

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***Abstract*—Resonance is an object in Organic Chemistry I course which involves multiple representations. The research aims to investigate the effects of multiple representations learning on the conceptual understanding of resonance in chemistry prospective teachers. The research method used in this study was a quasi-experiment. The research subjects were 56 second-semester chemistry education students who enrolled in Organic Chemistry I course. The research subjects were grouped into two classes which were the experimental class with multiple representations-based learning and control class with expository learning. Each class consisted of 28 students. The measuring instrument included 10 question items with three-tier test question type and a reliability of 0.634. The research result showed there was a positive effect on the use of multiple representations-based learning. This can be seen from the existence of a difference in the experimental and control classes' conceptual understanding. The conceptual understanding of resonance in the experimental class was higher than the control class.**

Keywords—multiple representations; conceptual understanding; resonance

I. INTRODUCTION

Chemistry is a material with abstract and complex characteristics, therefore there are still many students experiencing difficulties in studying it, even having a misconception. The difficulties and misconception encountered by chemistry students are due to the overwhelming abstract concepts which are not related to one another logically [1]. Organic Chemistry I is one of the required courses to be taught at Chemistry department at Universitas Negeri Malang. Resonance is one of the study objects in Organic Chemistry I course [2]. Resonance discusses the concept of how to depict the resonance structure, resonance hybrid, determining the structure of main contributor, and the stability of resonance structures. From the field study, it has been known that there were students who have difficulties and even encountered misconception in the Organic Chemistry I course, specifically in the concepts of resonance, intermolecular force, space isomerism, and organic reactions [3].

Resonance studies about drawing the resonance structures, resonance hybrid, and determining the resonance structure of the major contributor. The common mistakes made during the drawing of the resonance structure are 1) forgetting the charge. After drawing the resonance structure, the total charge of each resonance structure must be the same; 2) forgetting about the octet rules. It must be noted that the Lewis structure of each resonance drawn must be correct; 3) moving a single bond. In drawing a resonance structure, a single bond cannot be moved; and 4) not following the direction of the flow of the electron flow indicated by the curved arrow [4].

From the characteristics of resonance concept and the commonly made mistakes, there is a need of a teaching media to make it easily understandable, for example by using multiple representations including macroscopic, submicroscopic, and symbolic to reveal a clear phenomenon. Therefore, a learning innovation is needed to improve the students' understanding of Organic chemistry I material.

One of the learning innovations which is applicable in Organic chemistry I course particularly resonance deals with structure of compounds. Chemistry material has 3 levels of representations namely macroscopic, symbolic, and sub-microscopic [5]. A macroscopic level is a level which describes the real phenomena which can be observed by five senses, while sub-microscopic is the level which describes a particular level of a material which cannot be observed using senses such as the atom, molecule, and ion. The symbolic representation is a representation consists of diverse representations with figures. The figures cover all kinds of signs and symbols which are used to explain the chemistry concepts [6]. The three levels of representation need to be comprehended by the students so the students have a thorough knowledge of chemistry, particularly on resonance concept

Chemistry material particularly resonance will be very difficult to understand when the chemistry phenomenon is only based on the descriptions through lectures on a microscopic level without a description on the molecular level (submicroscopic) and symbolic, then it will be difficult to comprehend. Multiple representations give a positive effect on students' ability to construct arguments in the laboratory class though science writing heuristic strategy [7]. Multiple representations also help the students in problem solving on the chemistry concept about spectroscopy NMR [8]. Multiple representations support the writing-to-learn assignment as a pedagogical tool in improving chemistry learning at schools [9]. The use of other representations has also been performed to increase the students' understanding such as the transformation representation of macroscopic, submicroscopic, and symbolic [10]. There is a difference between instruction with Multiple Representations (IMR) and Instruction with Verbal Representations (IVR), where the students' scientific understanding taught by using multiple representations is better than students taught by using verbal representations [11].

Some researchers have conducted studies on the difficulties and misconceptions experienced by the students in higher education on Organic chemistry material. Study on the application of problem-solving has performed by using representations on the first-semester students at the University of Purdue who were taking Organic chemistry course [12]. In the case of writing systematic names (IUPAC system), students were able to write the names correctly in the straight chain structure but could not write the names on the cyclic structure form [13]. Presenting of functional groups Students also have difficulties for naming organic compounds in the presenting of functional group [14]. As well as stated by That based on 23 organic chemistry lecturers' perspectives in the USA, resonance is one of the concepts in the organic chemistry courses which is considered as difficult by the students [15]. Students still find difficulties in understanding the concept of resonance structure although Spartan Molecular Modeling software has been used in the learning [16]. The Resonance concept is one of the concepts learning by the chemistry prospective teachers in Basic Organic Chemistry course. It does not seem impossible for the chemistry prospective teachers also experienced difficulties and misconceptions in learning the concepts.

Based on the research results above, it can be said the organic chemistry particularly resonance concept is a hard concept to comprehend by students. Organic chemistry I is a basic concept to learn further organic chemistry concept such as predicting stability, intermediate and reaction product in organic reaction mechanism [3]. It means the use of multiple representations in learning chemistry helps the students' understanding well. Therefore, in learning resonance material, an innovative learning is needed such as learning using multiple representations.

II. Method

This research was conducted using a quasi-experimental design with a posttest-only control group design. The research subjects were 56 second-semester chemistry education students who enrolled in Organic Chemistry I course. The research subjects were divided into two classes, the experimental and the control class. The experimental class was taught with multiple representations-based learning, providing problems that must be solved in the student worksheet. The control class was taught using expository lectures. The instrument consists of a syllabus, semester lecture plans, student worksheets, and questions. The instruments to identify the conceptual understanding are ten question items of three-tier test question type with a reliability of 0.634. The instrument was in the form of three-tier test, which was multiple choice test with open-ended questions and Certainty of Response Index (CRI) scale technique developed by Hasan and have been modified by Potgieter, and Hakim [17-19]. The three-tier test instruments can be seen in the appendix. The difference of learning outcomes between the experimental and the control classes was analyzed by using t test.

III. Results and Discussion

The effect of using multiple representations on the conceptual understanding of resonance and misconception levels of chemistry prospective teachers were investigated. The results of the three-tier test data analysis on the resonance concept showed in table 1 which presented in the percentage distribution of chemistry prospective teachers' understanding of the concept, not understanding, and misconceptions, each question items on resonance concept from both classes. We obtained information on the chemistry prospective teacher students related to an understanding of the concept, not understanding, and misconceptions on the resonance between the experimental class and the control class. Meanwhile, the existence of differences in learning outcomes between the experimental class and the control class can be seen in table 2.

TABLE I. Recapitulation of Percentage of Conceptual Understanding, Not Understanding, and Misconception of Chemistry Prospective Teachers on Resonance in the Experimental and Control Classes

Question number	**Number of Pre-Service Chemistry Teachers' Conceptions**					
	Understand		***Not Understand***		***Have Misconception***	
	Experiment	***Control***	***Experiment***	***Control***	***Experiment***	***Control***
1	16	10	6	7	8	11
2	18	13	6	8	4	7
3	12	10	9	13	7	5
4	11	5	8	13	7	10
5	23	20	1	1	4	7
6	12	10	8	10	8	8
7	13	7	8	12	7	9
8	14	10	9	12	5	6
9	14	6	8	10	6	9
10	12	7	10	14	6	7
%	52%	35%	26%	37%	22%	28%

Table 1 shows that the percentage of student's conceptual understanding of experimental class (52%) was greater than control class (35%). This signifies that learning using multiple representations is very helpful for students' understanding of resonance. The characteristics of resonance involves numerous illustrations and depictions related to resonance structure, resonance hybrid, and determining the resonance structure of major contributor, so to comprehend them it needs a clear description related to the process of resonance occurrence. This situation is in accordance with the results of the study that there is difference between Instruction with Multiple Representations (IMR) and Instruction with Verbal Representations (IVR), where a scientific understanding of students being taught with multiple representations is better than the students taught using verbal representation [11]. On the other hand, with the chemistry prospective teachers not understanding the concept, the percentage of students' of not understanding the concept taught using multiple representations is lower (26%) compared to the class without using multiple representations (37%). Several reasons given by the chemistry prospective teacher in the experimental class appropriate with the theory on each question number is explained as follows.

The experimental class students in the question number 1 related to describing resonance theory, 16 out of 28 (57%) chemistry prospective teachers understood the concept. Through multiple representations-based learning with problem-solving strategy in student worksheets, almost 50% of the chemistry prospective teachers have answered correctly. Students who have a conceptual understanding with high confidence related to the question not according to the resonance theory, with correct reason. The example of student's correct answer is,

> *Resonance structure is two Lewis structure whose position of the atoms are same but different in terms of electron orders. If two or more Lewis structures have different atom position, then the structure is isomer. Thus, resonance structure is different from the isomer.*

The question number 2 determines the resonance structure of an organic molecule if the molecular formula is known. In this question, 18 (64%) experimental class chemistry prospective teachers have a conceptual understanding by answering correctly the questions which are not related to the resonance structure of the organic compound with the C3H6O3 molecular formula. The correct reason given by the student can be seen in figure 1.

Structure C has a different atomic structure from other structures.

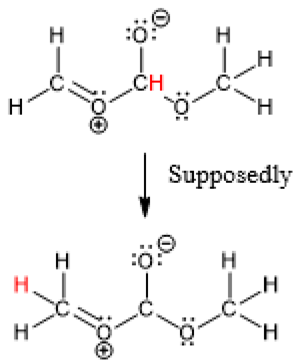

Fig. 1. Example of the correct student's reason on question number 2.

Questions number 3 and 4 related to differentiating the resonance structure and isomer. 12 (43%) students in the experimental class answered and gave the correct reason on the question number 3 about mentioning the pair of Lewis structure which belongs to the resonance structure. An example of the correct answer and reason can be seen in figure 2.

Structure I, II, and III are resonance structure. Structure IV is isomer because both structures have different atomic structures but have the same chemical formula.

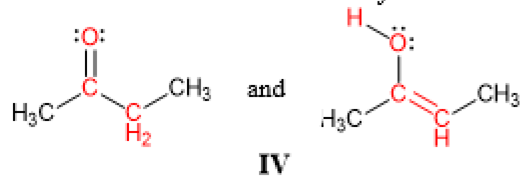

Fig. 2. Example of the correct student's reason on question number 3.

Question number 4 is related to selecting continuously the pair of Lewis structure which is isomer and resonance structure. 11 (39%) students in the experimental class were able to answer with the correct reasons. The examples of the correct answer and reasons can be seen in figure 3.

The pair of structure I and II are resonance structure because its atomic structure is the same but the elecetron order is different. Meanwhile, the pair of structure III and IV are isomers.

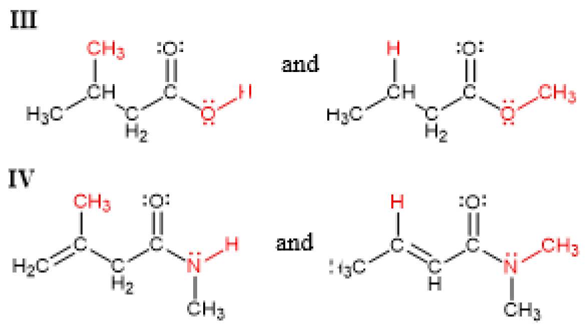

Fig. 3. Example of the correct student's reason on question number 4.

The same with question number 1, the explanation respondent for number 3 and 4 are according to the resonance theory concept, which stated that resonance structures are two Lewis structures which have the same atomic position in terms of electron orders [20]. Meanwhile, isomer is a compound which has the same chemical formula but different atomic structure.

Questions number 5 and 6 are related to drawing the resonance structure of the organic compound. On the question number 5, students were asked to mention the number of resonance structure of the organic compound with the CH_3CONH_2 molecular formula. 23 (82%) students in the experimental class answered the question number 5 with correct reason. The example of the correct answer and reason on the question number 5 can be seen in figure 4.

There are 3 resonance structures of CH_3CONH_2, they are:

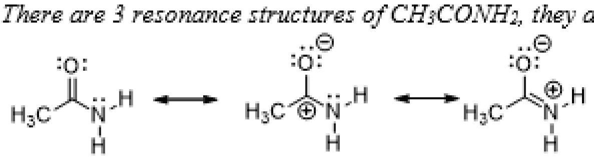

Fig. 4. Example of the correct student's reason on question number 5.

On the question number 6, it is given several compounds with their resonance structures. 12 (43%) students in the experimental class answered correctly. The example of the correct answer and reason can be seen in figure 5.

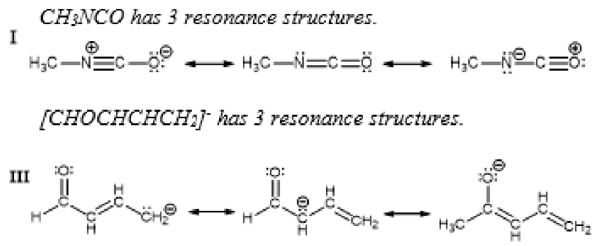

Fig. 5. Example of the correct student's reason on question number 6.

The answer reasons given by the student on the questions number 5 and 6 are according to the theory that the resonance structures are 2 Lewis structures which has the same atomic positions but different in terms of electron orders [21]. This in case, students had been able to draw the resonance structure well even though some of them still had difficulties and even misconception.

The questions number 7 and 8 are related to predicting the resonance structure of an organic compound from electron transfer and curved arrows. On the question number 7, students were to choose the appropriate resonance structure as a result of electron transfer based on the curved arrows. 13 prospective teacher students answered correctly which was E option. Several examples of the correct answer reason for the prospective teacher students are as followings.

- Answer A is wrong because there should be a formal charge of nitrogen atoms +1 instead of -1
- Answer B is wrong because the double bond at the end carbon atom disappears
- Answer C is wrong because the formal charge of oxygen -1 is not +1
- Answer D is wrong because it should be the formal charge of the carbon atom -1 is not +1. Besides that, the carbon atom should have one free electron pair.

On the question number 8, a curved arrow is given on a structure, the students are asked to choose the appropriate resonance structure as the results of electron transfer based on the curved arrows. 14 students of prospective teacher students in the experimental class answered correctly with E answer. The example of the correct answer and reason in question number 8 can be seen in figure 6.

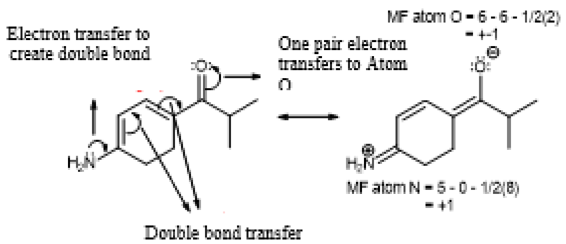

Fig. 6. Example of student's correct reason on question number 8.

The reasons given by the student on the question number 7 and 8 are according to the theory. The students have paid attention to atomic formal charge on the resonance structure obtained from electron transfer, drawing the resonance structure, and calculating the formal charge. The students did not understand the concept and experience misconception because they did not calculate the atomic formal charge on the resonance structure obtained from electron transfer, and considered that there is no correlation between the resonance structure and formal charge. This is in line with the research, Cooper conducted that the students who were taking the organic chemistry course could not relate Lewis structure of the organic compound with acidity/basicity, resonance structure, and a formal charge of the compound [22]. Several chemistry prospective teachers predicted the resonance structure of electron charge from its charge amount. They also chose the answer whose charge amount is the same before and after the electron transfer. This shows that some chemistry prospective teachers did not understand the meaning of curved arrows to show the electron transfer [3]. This is in line with the result of research which stated that students experience difficulties in comprehending the commonly used symbols in the organic chemistry such as line structure, compressed structure, Lewis structure, and curved arrows in the reaction mechanism [23,24].

The question number 9 is related to determining the structure of major contributor and additional contributor. The students gave the pair of resonance structure and were assigned to determine the pairs of the appropriate structure of major contributor and additional contributor.14 prospective teacher answered with C as the correct answer. The example of the correct answer and reason on question number 8 can be seen in figure 7.

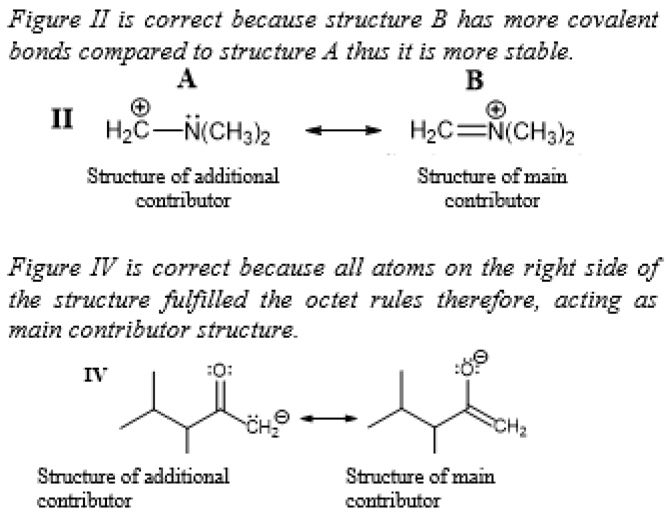

Fig. 7. Example of the correct student's reason on question number 9.

Question number 10 is related to determining the additional contributor structure when the resonance structures of organic compounds are known. 12 prospective teacher students in the experimental class answered correctly with D option. The example if the correct answer and reason given by the prospective teacher students is:

Structure D has the most atoms which do not fulfill the octet rules compared to structures B, C, and E, therefore it is less stable. Meanwhile, Structure A is not a resonance structure from an organic compound with a chemical formula of [$CH_3CH_2OC(CH_3)CHCOCH_3$].

The reason given by the students on the questions number 9 and 10 were according to the theory. Theoretically, the resonance structure is more stable when having more covalent bonds, more atoms fulfilling octet rules and as little as possible charge separation, and negative charge exist on the atom is more electronegative such as oxygen, nitrogen, and sulfur [25]. The low understanding and high misconception on the question number 10 was also caused by the chemistry prospective teachers considered that the stability of resonance structure only determined by the charge position on the existing atoms on the resonance structures. It is supposed that the resonance structures of no-charge atoms are the structures of the main contributor.

In table 1, it can be seen that the experimental and control class, there are still students who do not understand the concept and have misconceptions. The finding showed that misconception was hard to eliminate completely (zero misconception). This is in accordance to the previous research suggested that misconception cannot be removed at all, especially related to concepts involving submicroscopic and symbolic representations [26], whereas the characteristics of misconceptions are durable and firmly embedded in one's mind [27]. Although the misconceptions cannot be completely removed, it can be seen that the misconception in the experimental class (22.14%) is smaller than the control class (28.21%). This shows that there is an effect on the use of multiple representations on the learning process of intermolecular force material.

In the experimental class, the highest percentage of not understanding the concept and misconception occurred in the questions number 4, 6, and 10. The chemistry prospective teacher students still experienced difficulties in differentiating between resonance structure and isomer, drawing the resonance structure of the organic compound, and determining the structure of additional contributor. This can be seen from the few students who understand the concept of about 11 to 12 people, which is almost comparable to students who do not understand and experience misconceptions. This condition is due to the inability of students to describe resonance structures and weak understanding of related concepts to determine resonance structures. Students still assume that resonance structures are in equilibrium with one another. This can be seen from the students' answers that there is absolutely no description of the number of resonance structures that occur in a compound, do not associate formal charges with resonance structures, and do not understand the meaning of curved arrows to indicate electron displacement. Therefore, there are students who have difficulties and misconception.

This is in line with what has been conducted that based on the 23 chemistry lecturers' view in the USA, resonance is one of the concepts in the organic chemistry courses which is considered as difficult by the students [15]. Students believe that resonance is a fast change of electrons and in a balanced state. Therefore, it is possible that the chemistry prospective teachers also experience misconception on that particular concept. To find out the chemistry prospective teachers' level of understanding, not understanding and misconception of the resonance concept, a multiple representations-based learning and multiple choice test with open-ended reasons completed with CRI was administered.

In table 2 it can be seen that the average score of both classes was still far from the graduation standards in accordance with UM's academic guidelines. There were still students who have difficulty learning resonance. Besides that, there were also students who experience misconceptions. This happened because resonance concept was very abstract, so it requires high thinking skills and motivation to learn it.

TABLE II. RESULTS OF STATISTICAL CALCULATION OF EXPERIMENTAL AND CONTROL CLASSES' SCORES

Group	Average	Standard Deviation	t Test ($\alpha = 0.05$)	Identification
Experimental	52	15.88	0.000	Null hypothesis is rejected
Control	35	16.67		

The resonance concept will be easier if the chemistry prospective teacher students previously practice drawing the Lewis structure of a molecule if the chemical formula is known. Besides that, an emphasis on formal content in drawing the Lewis structure of a molecule is needed. The use of multiple representations to show the electron transfer is necessary to comprehend the meaning of curved arrows in drawing the resonance structures of organic molecules. The use of representations is also needed to show the difference of resonance structure and isomer. The chemistry prospective teachers also were given opportunities to draw resonance structure with known chemical formulas and to predict the stability of resonance structure.

From the above reality related to resonance material, the use of multiple representations affecting the conceptual understanding of chemistry prospective teachers. This contributes to the variety of conceptual understanding on resonance concept between experimental and control classes. The difference in both classes is strengthened by the significant difference test (t-test) in Table 2 that there is a significant difference between experimental and control classes, where the mean of experimental class (52) is greater than the mean score of control class (35).

The research results showed that the use of multiple representations helps the students in understanding the concepts of resonance which are abstract and needs a real depiction. Besides that, the use of multiple representations can also increase the mastery of resonance material. This can be seen from the result of students' conceptual mastery in the treatment class with multiple representations-based learning (experimental class) was better compared to the class without using multiple representations-based learning (control class).

Based on the research finding, the learning strategy of organic chemistry particularly the resonance material needs an improvement, namely presenting examples with more variety, and optimizing the use of multiple representations. The prospective chemistry teacher students can practice more to describe the molecular structure of a molecule if the chemical formula is known. In addition, it is important to emphasize the importance of formal content in describing the molecular structure of a molecule. The use of various representations to show the electron displacement is necessary in order to understand the meaning of curved arrows in describing the organic molecular resonance structures. The use of representations is also needed to show differences in the resonance structures and isomers. The chemistry prospective teachers are also given opportunities to practice drawing the molecule resonance structures which its chemical formula has been known and to predict the stability of resonance structure. Besides that, during group work of doing student worksheets, the time is paid more attention too.

IV. Conclusion

The use of multiple representations in the Organic Chemistry I course on the resonance material has a positive effect and helps the students in achieving a better conceptual understanding. This can be seen by the mean of the conceptual understanding of resonance in the experimental class (51.79) was higher compared to the control class (35.00). Moreover, the conceptual understanding of the student group taught using multiple representations-based learning was better compared to the expository group. Besides the use of modules and student worksheets based on multiple representations was able to improve the students' understanding and learning results.

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