Revealing students’ problems in learning synthesis organic

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Abstract. Students always show problems when learning about synthesis organic. Therefore, this study aims to reveal all students’ problems in synthesis organic chemistry. The participants of this research were 16 students of chemistry education in one of state university in Papua, Indonesia. This research was a descriptive research of which the students are given learning that concern to the concepts of the synthesis of organic compounds. The result shows that the students’ highest problem was in the concepts of stereochemistry product of organic compound, while the lowest one was in the concepts of the groups' functionality. Based on this study, the lecturer have to give a clearly explanations about the concepts of reagent, required condition, and related stereochemistry product.

1. Introduction

When students learning about the synthesis organic, there are a lot of problems that they have. It is because they must have a good understanding of the organic chemistry concept and need strategy in learning the synthesis organic. Students should be mastery in the concepts of stereochemistry, and regiochemistry of the organic molecule. As the addition, students also must consider how to improve chemoselectivity and safety of products that are produced.

In fact, lecturer does not emphasize the prerequisite concepts for use in synthesis and retrosynthetic analysis. This makes the students often just a recipient of passive knowledge. Lecturer need to teach students to integrate their basic knowledge and skill in synthesize organic compounds. Thus, students need to use their organic chemical concepts carefully. Students need to use their basic knowledge to design the various possible pathways of organic synthesis in order to obtain an existing synthesis stage design. Then the students need to re-evaluate the designs [1]. The previous research found that the success of person who solve chemical problems begins by describing the initial structure [2]. It can guide the way to solve the problem. In addition, we know there is a continuous relationship between one concept and others. This continuous relationship among the concepts can give impact for students’ ability to complete the task of organic synthesis.

Based on previous research, it is found that the task for students just only demand the explanation of general terms and explanation that related to the mechanism of reaction and the whole process of compound transformation. These tasks are only part of how students solve an organic synthesis problems. It is not focus on how students must answer the organic synthesis problems as a whole. Students can feel very difficult on the part where it should only be the initial stage of a series parts of the organic compound synthesis. The difficulties of students from the beginning of the tasks can impact
for students’ capability. They are not able to solve the more complex problems that are related to the problem of organic synthesis [3].

In the beginning, students must have the useful tasks in solving an organic chemical problem. Because it can help students feel easier to solve problems in higher difficulty level. Therefore, students need to be given organic synthesis problem by using mechanistic solution. Through this task, students will have a better understanding about how to solve organic chemistry problems mechanically [4]. Students who study organic chemistry need to practice doing the synthesis analysis of different molecule target and intermediates. It will forces them to think about the unusual, because in different from the conventional mechanism of organic synthesis or the simple context when they were first taught. While pedagogically will provide information about how student thinking process and how the students solve problems synthesis a target molecule compound. In this study, the aims is to investigate students’ problems when they learn the synthesis of organic chemistry.

2. Method
This research used descriptive method by using percentage analysis and involved 16 students from a state university in Papua who are in the third year. They were have attended the organic chemistry course 1 and organic chemistry course 2. The instrument used in this study is a multiple choice with reasons test and essay test. Questions were about the concept of functional groups of organic compounds, the structure of organic compounds, the stability of the carbocation, electrophile and nucleophile, reagents, conditions and products associated with the stereochemistry in organic reactions. These questions were considered important in learning the organic synthesis. Essay test included the problems of synthesis organic compound from analysis structure of starting material to synthesis the target molecule.

Example of multiple choice with reason test
1. Based on all the compound structures, which one is the more stable compound structure? Giving your explanation.

2. According to the following reaction. Choose a compound that will be a good electrophile on the reaction? Explain your answer.

Example of Essay test
Write down the synthesis of this molecule target from the starting materials that given below:

Figure 1. The example questions of multiple choice with reason test and essay test
Figure 1 show the example question of multiple choice with reason test and essay test. Data obtained that have been processed was from results students answer and used the percentage of students’ right answer to reveal their problem in synthesis organic.

3. Result and Discussion

The multiple choices test that the students have were concerning the consideration of fundamental concepts. It consists of questions about the functional groups and the bonds contained in the organic compound; structures of organic compounds and types of organic compounds; the stability of the carbocation of the organic compounds; electrophile and nucleophile; the reactants and reagents required to produce the appropriate product, also the major product produced by hold into stereochemistry. In the test about functional groups contained in organic compounds, students are seen to be able to connect the functional groups that exist in the compound with how the compound can make a bond. Almost all students can answer it correctly. This is understandable because this kind of question is just a repetition question [5]. Students do not have trouble with this question. Similarly with the functional group question, students also not have a lot of trouble to answer the question about structure of organic compound. Most students can answer correctly on this question. Because question only requires the knowledge aspects of the students concerned. On the next question, students are given the problem concerning to the stability of carbocation in organic compound. From the answer can be seen that students have started having difficulties to be able answering the question. It seems that students have difficulty to connecting their knowledge to answer the problem about carbocation. Only a few of students can answer correctly. Eventually, there are students that have a correct answer but do not give the reason according to the answer. It is known that the students are just guessing the answer from the test question. Lack of students understanding has an impact on the answers and explanations that are related. From the result of the students’ answers, it was found that most of students can not prompt explanations regarding the stability of the carbocation. In order to know students problems, they are given a conceptual question about electrophile and nucleophile concept. This concepts are very important in the synthesis of organic compounds. But the answers given by students related to the concept of electrophile and nucleophile are largely incorrect. It is because they only understand about nucleophiles and electrophiles associated with the existence of the positive and negative charges, that the electrophile and nucleophile possessed. They do not attributing it to the nature of acids and bases from the electrophiles and nucleophiles. The poverty of students’ understanding about the concept of electrophiles and nucleophiles can cause students difficulty in answer the other question. In this question, students should be able to choose specific reactants and conditions by the given product of an organic synthesis. Indeed, in the other question the product of the reaction existing. Students must choose from the reactants and conditions are given by taking into account the propensity of the stereochemistry to select the product. It appears that most of the students have difficulties in resolving this question. It is find that students cannot relate the reactants nor the conditions based on the reaction or product as a results. Students also cannot connect to the tendency of product and stereochemistry in the reaction. In table 1 we can see the percentage of students right answer.

Table 1. Percentage of student who have the right and wrong answer.

| Concepts                  | Percentage of students that have right answer (%) |
|---------------------------|--------------------------------------------------|
| Functional Group          | 79                                               |
| Organic compound structure| 57                                               |
| Carbocation Stabilization | 22                                               |
| Electrophil and Nucleophil| 36                                               |
| Reagent and condition     | 15                                               |
Students' have low skill and ability to generalize a reaction or make connections between reactions effect of it. It can cause by students' inadequacies that them can not think other way to solve the problem. It can be said that they do not have experienced in meaningful learning [9]. Furthermore, in the essay test contain the synthesis analysis. The first question concerning the analysis of the retrosynthetic analysis, and the students asked to identify the part of the specific reaction that leading to a complex product. The questions are directed encouraging students to discover patterns of the product structure. Like the previous research, where the case that given to the students are driven them to synthesis the specific product like Aldol condensations [10].

For the first essay question, students initially practiced finding functional groups that existed on the target molecule. For students, question like this is very different from the problem that usually they get it, because in this part, they have to determine the site that need to react. Based on the students answer, it obtain that most students experience constraints when answering this question. We find that students still remember clearly the structure of compounds and the resulting of compounds product that familiar to them. Likewise in the synthesis about Aldol condensation, most students answer the site's possibility of an Aldol reactions are present in the presence of three C-C rings that binding to the carbonyl group present. The students give the answer without considering the existence of the Aldol condensation structure on a complex compound.

In the next question, students are asked to identify the reactions that necessary can make the bonds in complex organic compounds structure. For this problems, actually student already have a list of possible reactions that form such bonds from the previous organic chemistry lectures in class. They should consider very all the reactions that have been studied. They are also encouraged to think of some answers or strategies. In the second question, students are presented with a complex target of the molecule and ask how they will make a particular bond. Students only are able to identify the reactions that they usually used it. Also we connected it with concept of bonding that has been given to students. But it looks obvious that students are only accustomed bonding formation on simple compounds and they do not familiar to see bonds that occur in complex compounds.

Table 1 shows that students have highest percentage in right answer in functional group (79%). Student have lowest percentage in reagen and conditions (15%) and product of organic synthesis and stereochemistry (14%). Table 1 also shows that students can only succeed well in answer the question about functional groups concepts because it is an easy question for them. It is possible because the question of functional groups and structures of compounds are often given. It can be only repetition or a form of memorization for students. It is also can attributed that the organic chemistry learning pattern applied by lecturers only on the aspect of knowledge. It shows that the learning process just provides repetition of the definition problems and does not emphasize the existence of meaningful learning that involves students' thinking skill.

The students' answer to the question of organic chemistry concepts show that students were not been able to understand concepts related to the organic synthesis problems. In general, students just provide the answers which are related to the knowledge or memorization only. It have been known that students' tendency to memorize a set of rules and previous reactions in organic chemistry can inhibit students learning process [6, 7, 8]. There was the link between students’ concept and students' answer to solve organic chemistry problems. It was found that the difficulty of students in mastering the concepts related to how the students solve a problem of organic chemistry. We find that because of students’ lack understanding of concepts so they cannot apply the concepts of organic chemistry in answering problems. Moreover, students can only use the reaction of organic compounds that are familiar with them. It make students unable to provide problem solving strategies if they encounter the new organic compound reactions problems.

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In the third question are adopted by previous research, students were asked to identify the best starting material in order to produce a particular product. At the beginning, students must identify the correct type of reaction to produce the product. Then they have to perform the atomic calculations to identify the starting material that most appropriate. At last they must use a mechanism in combination with functional groups in the starting materials and products to determine the appropriate pair of compounds [11,12].

Students find problems to identify the required reactions and drawing the required starting material. In answering this problem, there are few students who began to explain using the synthon approach. But most of the students not use the synthon approach. Even though, the synthon approach began to be taught at the beginning of the discussion on the disconnection of organic compounds. They basically cannot distinguish with both electrophile and nucleophile. Thus students do not use mechanistic thinking processes and rely solely on their memory of chemical principles. In this part, it is visible that students are not familiar with the problems given by using complex compounds. That is why they do not know how to solve the problem.

In the question of the synthesis organic compounds, students are required to write the synthesis of organic compounds. They can use the list of reagents, starting materials, products, names of reactions, and electrophiles that already given. It appears that the students only tend to choose from the list of reactions that are familiar to them. There is a tendency of students to close the synthesis answer with the existing list that they have it. This makes the students cannot express the idea of its own synthesis. In this question most students cannot write the synthesis of organic compounds. In the question the students is asked to write the synthesis of an organic compound by choosing based on the list of reagents that already available. Students cannot answer correctly this question. This is because they do not mastery in the conceptual of the reactions of organic compounds. In addition, they have lack of ability to work in mechanism reaction. According to the students answer of all the questions we can make list of students’ problems such as in Table 2.

### Table 2. Students’ Problems in Learning Organic Synthesis

| Organic synthesis Problems                                      | Explanation                                                                 |
|-----------------------------------------------------------------|-----------------------------------------------------------------------------|
| Identify the specific part of the reaction the complex compounds | The students gives the answer without considering the existence of the Aldol condensation structure on a complex compound. |
| Identify reactions, bonds, of complex compounds                 | Students can not apply their own conceptual understanding related to reaction and bonding to complex compounds. Students are not familiar with the problems associated with complex compounds. |
| Identify starting material compounds from complex compound products | Students who are less understanding associated with the concept of electrophiles and nucleophiles of students making them unable to answer the problem. |
| Propose a composite retrosynthetic analysis based on the list of reactions given | The lack of students are specifically related to reagents, products and conditions required for specific organic farming therefore students can not answer the organic synthesis problem. |
| Propose synthesis, based on starting material compound, product and choice of reagents provided. | Students can not solve the problem of organic synthesis by using the reaction mechanism. |

Table 2 show each type of synthesis question aims to be able provide specific learning outcomes. Each question is designed to help students demonstrate specific knowledge. From student answer we know how students’ problems. According to early research, if students rely solely on heuristic ability,
there will be not effort or process skills from the students to reach the truth of the answer [13]. Sometimes, when students use practical rules that help students simplify the task and solve problems, but it has been shown often lead students do not understand the existing concepts [14,15,16]. If students do not use the strategies and skills intended, they will not be able to achieve the intended learning outcomes, although they may be able to answer the questions given. Students who serve as subjects in this study who have not become experts in organic chemistry, they must demonstrate behaviour consistent with problem solving strategies successfully used by experts.

In this research we find that complexity of compounds is considered as a factor that can affect how students work to solve the problems. Based on this synthesis question, it states a gap between the knowledge possessed by students and the skills to achieve synthesis and retrosynthetic analysis. It is known that students rarely involved a problem solving related to the reaction mechanism and not accustomed to applying the synthon approach to complex compounds. It found in the early research that for higher levels of thinking ability it is necessary to encourage students to change their learning habits from memorization to meaningful learning [17], and this needs to be done to achieve higher levels of learning outcomes. Students make a study based on authentic and tangible issues similar to the complex problems. It is like scientists facing that have an impact on improving students' ability to think critically and learn independently and gain learning experience. This is a process of assimilation that must be passed by students to be transformed into practitioners or scientists in the field of organic chemistry [18].

The practice of organic synthesis carried out by students in the laboratory can help the purpose of the curriculum. It helps students to be able to improve affective, psychomotor and cognitive aspects and can even evaluate students on these aspects [19,20]. Previous research also found that through the experiment of synthesis of organic compounds in the laboratory, students are involved in an authentic problem in a specific domain [21].

4. Conclusion
The results showed that the students have a lot of problems in the concept of reagent, required condition and related product stereochemistry of organic compound. This indicated that lecturer should make a study based on authentic and real problems that are similar to the complex problems faced by scientists who have an impact on an increase in the ability of students to think critically and learn independently and gain a learning experience.

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