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# STUDENTS' DIFFICULTIES IN SOLVING SYNTHESIS ORGANIC COMPOUND PROBLEMS

**Lusia Narsia Amsad [1,✉], Liliasari S [2], Asep Kadarohman [3], Ratnaningsih Eko Sardjono [4]**

[1,2,3,4]Department Science Education, School of Postgraduated Studies, Universitas Pendidikan Indonesia, Bandung - Indonesia
[1]Department Chemistry Education, Faculty of Teacher Training and Education,Universitas Cenderawasih - Indonesia
[2,3,4]Department of Chemistry Education, Faculty of Mathematics and Science Education, Universitas Pendidikan Indonesia, Bandung – Indonesia

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## *Abstract*

Solving the synthesis problem of organic compounds requires the understanding of certain organic chemical concepts. Students need to integrate organic chemical concepts to analyze the synthesis stage of organic compounds. Therefore, purposed of this research is want to find the difficulties possessed by students in solving organic synthesis problem. The participants of this research are 14 students of chemistry education in one state university in Papua, Indonesia. The type of this research is descriptive research. The research using multiple choices with reasoning test and essay test as the instruments, that consist of 6 items of multiple choices and 3 essay items. The results analyze by percentage and described. In this research, students are given issues concerning to the concepts of organic chemistry and the synthesis of organic compounds. The result shows students' understanding on the concept of functional group of organic compound is 79%, organic compound structure is 57%, organic stability is 22%, electrophile and nucleophile is 36%, while the concept of reagent, required condition and related product stereochemistry of organic compound less than 20%. It shows students having more difficulties in the concepts of reagent, required condition and related product stereochemistry of organic compound.


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✉Correspondence author:
**Lusia Narsia Amsad**
Departement Science Education, School of Postgraduated Studies
Universitas Pendidikan Indonesia, Bandung, Indonesia
Email: lusianarsiaamsad@gmail.com

## INTRODUCTION

The synthesis of organic compounds is one of the subjects contained in organic chemistry. For learning this subject, students must have an understanding of the organic chemistry concept and need strategy. Students also must considering about stereochemistry, regiochemistry of the molecule target. In addition students also must consider how to improve chemo-selectivity, safety of products that are produced. Students have to think to minimize the required costs and waste generated. In reality in the learning class, lecturer does not emphasize the learning in study of the prerequisite concepts for use in synthesis and retrosynthesis. 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 (Flynn, 2014).

Bodner and Domin (2000) state that the success of a person who solve chemical problems begins by describing the initial structure. It can guide the way to solve the problem. In addition, we known there is a continuous relationship between the concept with the other. This continuous relationship between the concepts can give impact for the 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' capable. They are not able to solve the more complex problems that are related to the problem of organic synthesis (Strickland et al, 2010).

Students must given useful tasks in solving an organic chemical problem from the beginning. Because it can help students will 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, studentswill have a better understanding about how to solve organic chemistry problems mechanically (Anderson, 2009).

Students who study organic chemistry need to practice doing 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 to solve problems synthesis a target molecule compound.

In previous studies they also learn about how students complete a retrosynthesis analysis of organic compounds. In this study, the aims is to investigate the extent students experience with organic chemistry when they haveto solve the organic synthesis problems. In this study, the studentst tends to be encountered as an organic chemist (Bhattacaryya & Bodner, 2014). Based on all the previous researches, this research want to find the students difficulties when they answer the organic synthesis compound.

## METHODS

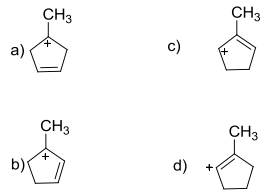
This research uses descriptive method by using percentage analysis and involves 14 students from one state university in Papua who are in the third year in academic year 2017/2018. They are already attended the organic chemistry courses 1 and 2. The instrument used in this study is a multiple choice with reasons test and essay test.

Questions of multiple choice with reason taken in regard to 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 are considered important in solving organic synthesis problems. Essay test includes the problems of synthesis organic compound from analyze structure of starting material to synthesis the target molecule.

In the figure 1 shows the examples of the multiple choices with reason test and essay test that used as the instruments.

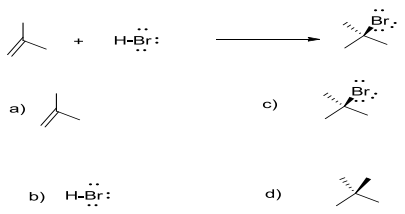
**A. Example of multiplechoice test by using reason**

**1. According to the compound structure below, which one is the more stable carbocation? Give it explain your answer.**




**Reason :----------**

**2. Look at the reaction,choose one compound that can be a good electrophile in the above reaction? Explain your answer.**




**Reason :----------**

**B. Example of essay test**

**Write down the synthesis reaction from the avaible target molecule and starting material below.**

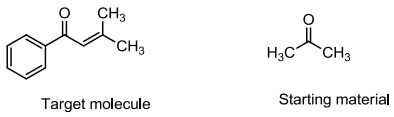



**Figure 1.** The example questions of multiple choice with reason test and essay test

Data obtained that have been processed is from results students answer. The data come from 6 items about multiple choices with reasons that used to know the students understanding about the concepts. They have right answer if connection of the answer and the reason is true, or wrong if the answer and reason connection is wrong, or correct answered but the reason is wrong or incorrect if no reason, and no answer. Then we will compare with students answer in 3 item of essay test to find the students' difficulties in synthesis organic problems.

After that we tabulated for a number of students who answered correctly and wrong, and make a percentage of each students answer. Then we made a table for grouping the students understanding level from the percentage number of students who answered correctly for each question, with the following criteria in the table 1.

Table. 1 The Categories of Students Understanding

| Students understanding level | Percentage number of students that have a right answer (%) |
|---|---|
| Excellent | 81-100 |
| Good | 61-80 |
| Adequate | 41-60 |
| Less | 21-41 |
| Very Less | 0-20 |

According to Table 1, student have an excellent understanding if the percentage number of students that have the right answer beeween 81-100%, and the very less understanding if the percentage 0-20%.

## RESULTS AND DISCUSSION

The multiple choices test that given to the students concerning the consideration of fundamental concepts. It consists 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 according to Raker and Holme (2014) this kind of question is just a repetition question. 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 thatstudents 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. Also, 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 their answers and explanations that are related. From the result of the students' answers, it find that most students can not prompt explanations regarding the stability of the carbocation.

In order to know students conception, they are given a conceptual question about electrophile and nucleophile concept. These 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. Student 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 2 we

can see the percentage of students right and wrong answer.

Table 2 Percentage of student who have the right and wrong answer.

| Concepts | Percentage of students that have right answer (%) | Percentage of students that have wrong answer (%) |
|---|---|---|
| Functional Group | 79 | 21 |
| Organic compound structure | 57 | 43 |
| Carbocation Stabilization | 22 | 78 |
| Electrophil and Nucleophil | 36 | 64 |
| Reagent and condition | 15 | 85 |
| Product of organic synthesis and stereochemistry | 14 | 86 |

From Table 2 we find 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%). Based on Table 2, we can categories level of students understanding on each concept likewise in table 3.

Table 3. Level of Students Understanding on each Concept

| Concepts | Number of students that have a right answer (%) | Students Understanding level |
|---|---|---|
| Functional Group | 79 | Good |
| Organic compound structure | 57 | Adequate |
| Carbocation Stabilization | 22 | Less |
| Electrophil and Nucleophil | 36 | Less |
| Reagent and condition | 15 | Very Less |
| Product of organic synthesis and stereochemistry | 14 | Very Less |

Table 3 shows that students can only succeed well in answer the question about functional groups concepts cause the level is good. Students understanding level in the structures of organic compounds is adequate. 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. As in table 2 then we can create a graph of the number of students who answered correctly as in Figure 1 below.

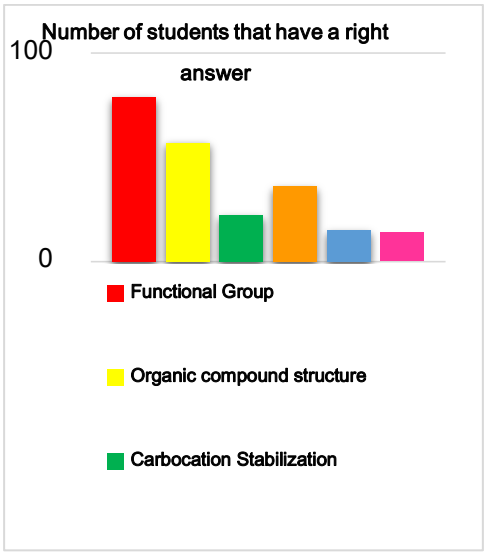



Figure 1 Graphic of students that have a right answer.

The students' answer to the question of organic chemistry concepts show that students 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 (Anderson & Bodner, 2008; Bodner, 2009; Grove & Bretz, 2012).We can make the link between students' concept and students' answer to solve organic chemistry problems. We find 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.

In addition, 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. Students' have low skill and ability to generalize a reaction or make connections between reactions effected 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 (Grove & Bretz, 2012).

Furthermore, in the essay test contain the synthesis analysis. The first question concerning the analysis of retrosynthesis. In this question, 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 reseach, where the case that given to the students are driven them to synthesis the specific product like aldol condensations (Flynn, 2011).

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 result 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 be 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.

In the third question are adopted by previous research (Sauers & Morrison, 2007; Straumanis & Ruder, 2009), students were asked to identify the best starting material in order to produce a particular product .At first 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.

Indeed, for students find difficulty 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. Eventhough, 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' difficulties such as in Table 4.

Table 4. Students' Difficulties on Organic Chemistry Concepts that Used to Answer Organic Synthesis Problems

| Organic synthesis Problems | Organic Chemical Concepts that used*) | | | | | | Explanation |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | |
| **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 retrosynthesis 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 so that 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.** |

**Explanation: 1= cluster function of organic compound, 2 = structure of organic compound, 3 = stability of carbocation, 4 = electrofil and nucleophiles, 5 = reagent and condition on organic synthesis, and 6 = products synthesis of related organic stereochemistry**

Each type of synthesis question aims to be able provide specific learning outcomes. Each question is designed to help students demonstrate specific knowledge. According to Shah & Oppenheimer (2008) if students rely solely on heuristic ability, there will be no effort

or process skill from the students to reach the truth of the answer. Sometimes 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 (Taber, 2009; Maeyer & Talanquer, 2010; McClary & Talanquer, 2011).

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.

Heiser and Tversky (2006) revealed a mental model that emphasizes function rather than form. Students who serve as subjects in this study who have not become experts in organic chemistry, they must demonstrate behavior consistent with problem-solving strategies successfully used by experts.

For this research we find that complexity of compounds is considered as a factor that can affect how students work to solve the problems it faces.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 (Grove & Bretz, 2012), 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 (Flynn & Biggs, 2011).

The practice of organic synthesis carried out by students in the laboratory can help the purpose of the curriculum. It help students to be able to improve affective, psychomotor and cognitive aspects and can even evaluate students on these aspects (Bretz et al., 2013; Galloway & Bretz, 2015). Even according to Bhattacaryya and Bodner (2014) through the experiment of synthesis of organic compounds in the laboratory, students are involved in an authentic problem in a specific domain.

## CONCLUSION

The results showed students having difficulties especially in the concept of reagent, required condition and related product stereochemistry of organic compound, because their understanding for each concepts are in very less categories.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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