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Lina Fauzi'ah, Artina Diniaty, Widinda Normalia Arlianty, and Beta Wulan Febriana

Modified Spiral Organic Curriculum on Organic Chemistry Courses for Chemistry Education Undergraduate Students

Lina Fauzi'ah[1,a)], Artina Diniaty[1,b)], Widinda Normalia Arlianty[1)], Beta Wulan Febriana[1)]

[1)]*Department of Chemistry Education, Faculty of Mathematics and Sciences, Universitas Islam Indonesia, KampusTerpadu UII, Jl. Kaliurang Km 14, Sleman, Yogyakarta,*

Corresponding author: [a)]lina.fauziah@uii.ac.id,
[b)]artina.diniaty@uii.ac.id

Abstract. This study aimed to know the effect of implementation modified spiral (or two-cycle) organic curriculum for Chemistry Education Undergraduate Students. The changing of curriculum that impacted in the organization of topics, was due to the low of student's achievement in Organic Chemistry courses. In a spiral curriculum, the first cycle was surveyed course which students learned about general organic chemistry that must be studied in year-long courses in the previous curriculum. The survey course discussed topics in less detail but with some emphasis on the topics that related to the chemistry for high school. The second course was the spiral of the first cycle that discussed the same chapter but in a more advanced discussion. In this cycle, students began to study about stereochemistry, mechanism of organic reaction and its application for daily need and industry. From the data analysis, there was a significant difference of students' achievement that learned with previous and spiral organic curriculum. It can be concluded that this modified curriculum is more appropriate to be applied for Chemistry Education students.

INTRODUCTION

Organic chemistry topics in high school were studied in Grade X and XII. The topics were discussed about hydrocarbon, haloalkanes, benzene, and their physical properties, the use, and also their organic reaction. In addition, it was also discussed about the forming and the use of crude oil in daily need. In Grade XII students were introduced with a functional group of organic compounds, such as alcohol, ether, aldehyde, ketone, carboxylic acid, and ester. So, Organic Chemistry courses must be studied by Chemistry Education's undergraduate students with some emphasis in topics that related to chemistry topic in high school.

Organic Chemistry courses were studied by Chemistry Education students in semester II and III. Unfortunately, the students must study it in first year which they need some adaptation in college circumstances.These courses were very important for candidates of a chemistry teacher, especially for professional competences. In Chemistry Education Department, Faculty of Mathematics and Sciences, Islamic University of Indonesia, this course were held to achieve learning outcome, CP P1 that aims to master concept and principle about structure, dynamics, chemical energy, to master basic principle of separation, analysis, and characterization that needed to understand chemistry for high school. With the learning outcomes that must be achieved, not only the students must master and understand concepts of chemistry but also expected can explain the concept to high school students. Therefore, teacher candidates must master and understand the concepts of chemistry that more advanced in order to can teach well.

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Organic Chemistry courses topics are filled with drawing structures, space-filling models in 2D and 3D, Newman and Fischer projections, and mechanism of organic reaction that need the ability of students to imagine thespatial arrangement atoms in molecules and represented it in 2D paper as 3D image. It was found that learning Organic Chemistry requires a completely different skill set, i.e. visualize spatially, recognize patterns, and think critically [1]. Therefore, the discussion of this topics must be clear and detail. Besides that, it must be considered about students' ability level when those topics were discussed.

Chemistry Education students of Islamic University of Indonesia, had lacking ability in understanding mechanism reaction. It can be seen from the ability of students to answer the final exam test which 51.4% of students had scores below C. Similar problem was also faced by students of Miami University [2], California State University, Los Angeles (CSULA)[3], Saint Mary's University of Minnesota [4] and Wittenberg University [5]. At Miamy University and CSULA, there were high attrition rate issues. Organic chemistry was assumed as the most difficult course [4]. There were students felt overwhelmed and frustrated in studying organic chemistry [5].

It was predicted that the problems in studying organic chemistry were monotonous learning [3], "elephantiasis" of year-long textbook [5], only a small fraction of the literature on the learning of organic chemistry that focused on the learning experience [6], students did not study enough [3], less useful curricula that related to topics' organizing [4], student assumption about organic chemistry [2], the fundamental change in thought process when students move from general chemistry to organic chemistry course that have different topics' characteristic [7], tend to memorize the arrow direction on the mechanism without understanding the concept of electron movement in mechanism reaction [8] and the concepts are largely hierarchical and difficult to master by simple memorization [9]. Monotonous learning made the students' motivation to learn decreased. It could be resolved with active learning design. A summary text book could be written in order to the students did not feel overwhelmed. Hereinafter, a modified curriculum could be applied so that it was useful and suitable for students' ability.

At Chemistry Education Department, Islamic University of Indonesia, the students in First Grade (2nd semester) should be able to understand organic functional groups, included alkanes, alkenes, alkynes, alcohol and ether with the topics were nomenclature, physical and chemical properties, synthesis, related organic reaction, and its mechanism. Students should master about arrows in mechanism reaction, identify the prediction of mechanism occur, and determine mayor and minor products in organic reactions. It seems that students were overwhelmed and not ready to study it in first grade. Hence, it was needed reorganization of topics that can be done with curriculum revision. Some topics must be postponed to next semester and some of them must be emphasized.

At Chemistry Department of Miami University, USA, it was developed spiral (or called two cycles) curriculum for Organic Chemistry courses [2]. The difference of spiral and traditional curriculum was located in the scope and sequentially of a topic. In a spiral curriculum, a broad and general overview of organic chemistry was learned during the first semester (Organic Chemistry I or first cycle). The next semester (Organic Chemistry II or second cycles), it was explored about the important topic in more detail. In the first cycle, students studied about organic functional groups, included alkanes, alkenes, alkynes, alcohol, ether, aldehyde, ketone, carboxylic acids and its derivatives. It was discussed how to name organic compounds, their chemical and physical properties, and also some basic mechanistic process. At the second cycle, students revisit studied the topics in the first cycle but in more advanced, especially focusing on mechanism and modern reactions. The detailed topics in first and second cycles were shown in Fig. 1**.**

The two-cycle approach has implemented at Wittenberg University [5]. There were some topics that must be emphasized in the first cycle, i.e. structure and bonding of organic molecules, the fundamental of resonance and aromaticity, stereochemistry concepts, nomenclature, and the functional group's concept. The reaction of mechanism and some of mayor reaction must be introduced. In addition, spectroscopy was studied only in the laboratory portion. The others topics were left until the second course. The topics that must be studied in first and second cycles has be reorganized by Gravert [4]. Gravert et.al have postponed the topics that related to physical organic chemistry, included Alkanes and Cycloalkanes conformations, chirality and stereochemistry, substitution and elimination reactions, conjugation, aromaticity, ethers and epoxides. It was difficult to choose the topics that must be postponed and also determine the depth of the topics. For example, in the chapter of reaction of Alkenes, some topics i.e. free radical addition of HBr, acid-catalyzed hydration, oxymercuration-demercuration, hydroboration-oxidation, osmium-catalyzed oxidation, ozonolysis, epoxidation, and carbene addition have been delayed [4].

In order to solve the problem that was occur, it was needed to be studied about the implementation of the spiral (two-cycle) organic curriculum for Chemistry Education Undergraduates students to increase students' understanding in Organic Chemistry courses. In this paper, it would be discussed about the implementation of modified spiral curriculum in the first cycle to students' understanding of Organic Chemistry course.

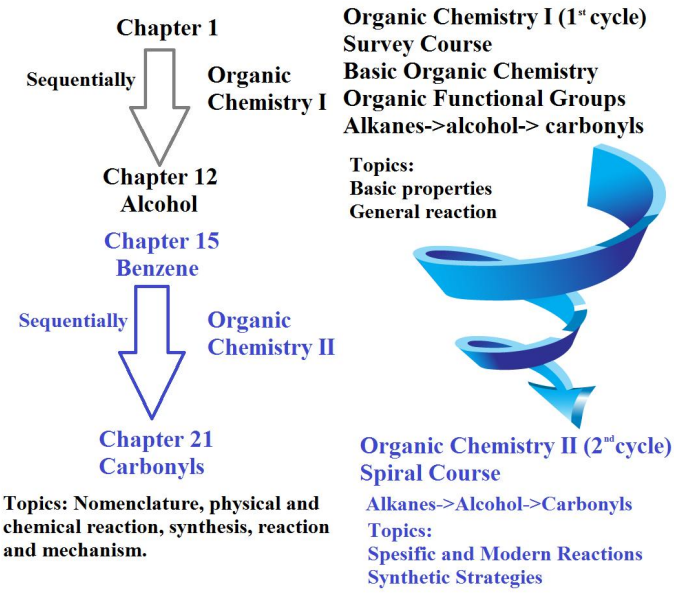

FIGURE 1. Comparison of the Traditional Organic Curriculum and the Spiral Organic Curriculum

EXPERIMENTAL

This study was experimental research that aimed to determine the effect of spiral organic chemistry to students' understanding of Organic Chemistry courses. The effect could be seen from the different of students' achievement that was studied in previous curriculum and spiral curriculum with the assumption that they have same prior knowledge. Students' achievement was obtained from final exam of course. The data that collected, were tested for normality and homogeneity. To determine the impact of modified spiral curriculum, it would be compared the students' achievement on the same topics. For learning that used previous curriculum (in academic year 2015/2016), it would be used the final exam for Chemistry Organic I course, while for spiral curriculum (in academic year 2016/2017), it would be used the midterm exam.

RESULTS AND DISCUSSIONS

The spiral organic chemistry curriculum has been modified and applied for students of Chemistry Education, Islamic University of Indonesia. In this curriculum, the topics did not study sequentially, but in "spiral term", the topics that have been studied in the first course, explored again in more advanced in the second course. The first cycle was a survey course, students studied Organic Chemistry in the surface with some emphasis for several topics. Some of the topics that must be studied in the first or second cycle must be adjusted with the learning outcomes that must be achieved and students' ability. It seems that the students have not been able to study about stereochemistry and mechanism reaction. They need some adaptation in thought process to understand the material, especially the student studied Organic Chemistry in first year [7]. Memorization may have been an effective study strategy in high school, whereas elaboration and critical thinking are required in college [1]. So that in this modified spiral curriculum, those topics were postponed until the second cycle. The reorganizing of topics in Organic Chemistry course of our Department was shown in Table 1.

The Emphasis for the first cycle on spiral curriculum was done for some topics, i.e. structure and bonding of carbon-carbon single, double, and triple bond, nomenclature, the nature of a functional group that impacted to their physical properties, include boiling point, solubility, polarity, and acidity. In addition, in the end of the semester, it was learned about petrochemicals. The topics that were mentioned must be discussed in more detail due to the relation with chemistry topics in high schools. So, from the first cycle, students must master the

fundamental of functional group and the application in daily need of industry (studied from the chapter: petrochemicals).

TABLE 1. The Comparison of Studied Topics on Organic Chemistry Courses

Previous Curriculum	Modified Spiral Curriculum
Organic Chemistry I	**Organic Chemistry I (First Cycle)**
Introduction Structure, bonding, and properties of organic compounds Alkanes and Cycloalkanes Alkenes Alkynes Alkyl Halides Petrochemicals Note: the discussion of functional groups' chapter included nomenclature, stereochemistry, physical and chemical properties, synthesis, a reaction that related, mechanism reaction, i.e. S_N1, S_N2, E1, and E2.	Introduction Alkanes and Cycloalkanes Alkenes Alkynes Alkyl Halides Petrochemicals Alcohol and Ether Aldehyde and Ketone Carboxylic acid and its derivatives (ester, acid halides, anhydride acid, nitrile, and amide) Amines Polymer Note: the discussion of functional groups' chapter included nomenclature, physical properties included boiling point, solubility, and polarity, and some basic organic reaction (without explanation about mechanism).
Organic Chemistry II	**Organic Chemistry II (Second Cycle)**
Alcohol and Ether Aldehyde and Ketone Carboxylic acid and its derivatives (ester, acid halides, anhydride acid, nitrile, and amide) Amines Polymer Note: the discussion of functional groups' chapter included nomenclature, conformation, physical and chemical properties, synthesis, a reaction that related, and mechanism reaction.	Introduction Stereochemistry, Isomer, conformation, conjugation, configuration, chiral molecules. Organic Chemistry Reaction Nucleophilicity, electrophilicity, arrows in mechanism, kind of organic reaction, predict mechanism reaction, a diagram of energy, intermediates, transition state, the rate of reaction. Substitution Reaction: Reaction of Alkyl Halides, alcohol, and related compounds (S_N1 and S_N2). Elimination Reaction: Reaction of Alkyl Halides, alcohol, and related compounds (E1, E2, and E1cb). Interconversion of Functional Groups Synthesis of Alcohol, Ether, Ester, Alkyl Halide, Amine, Hydrocarbon, Open ring Epoxide Elimination of Alkyl Halides Addition Reaction to the Alkenes and Alkynes Addition to the Carbonyl Group: Reaction of Aldehyde and Ketones Substitution at the Carbonyl Group

The emphasis topic that must be learned was done with students did exercises in white board. Previously, the lecturer has given some sample questions that also written in white board. Drawing organic structure on the white board has positively affected to students' motivation and understanding. It could teach students steps to solve the questions. It was accordance with Professor Mwaamba's belief that drawing each organic compound structure in chalkboard was the most effective to explain the topics rather than using Power Point Presentation [10]. Although it was not entirely agreeing with that statement, but explained some topics that related to nomenclature with drawing it in whiteboard could help students to understand.

The survey course in the first cycle made students learn organic chemistry in the surface, so it also was discussed about organic molecules in daily need. From that approach, it could motivate students and fix students' assumption about Organic Chemistry course. From topics' reorganizing that conducted in the spiral curriculum, it turned out to give positively image of this course. This cycle made this course was not as difficult as students had initially anticipated [2].

The second cycle began with the introduction that discussed organic reaction in daily need and industry. It was used to attract students' interest in organic chemistry and gave them an overview that in this semester they must study all about organic chemistry reaction. Stereochemistry was given in this cycle due to students in first grade still hard to construct and represent organic compound in three dimension (3D). Organic reaction and mechanism chapter was the soul of the second cycle. It must be taught clearly and detail, because the success of students on studying the next chapter depended on it. Students must be able to recognize the nucleophile and electrophile in an organic reaction. From that ability, they can predict the product of a reaction. The average of student's achievement on the midterm and final exam on Organic Chemistry I course was shown in Fig. 2.

The comparison of students' understanding of Organic Chemistry course between previous and spiral curriculum was done for the same topics. So, it was compared the scores of the final exam for the students that learned with previous curriculum and midterm exam in the spiral curriculum with the assumption that difficulty level of topics was similar. The data obtained was not normal, so the difference was tested with the non-parametric test, i.e. Mann-Whitney U. The analysis of the data showed that there was a significant difference between learning that used the previous and spiral curriculum. It was shown in Table 2.

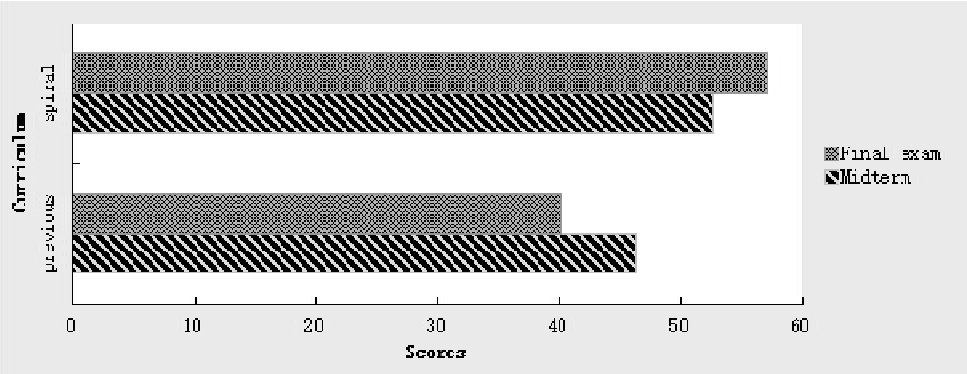

FIGURE 2 The Average of Student's Achievement in Organic Chemistry I Course

TABLE 2. Data Analysis of Students' Achievement

Curriculum	Average Score	Sig. of Normality Test (Kolmogorov-Smirnov)	Mann-Whitney U
Previous	40.159	0.026	0.01
Spiral	57.144	0.200	

After all, this result was only from the first cycle that was obtained on Organic Chemistry I course. In the next semester, it must be observed again, the effect of this modified spiral curriculum.

CONCLUSION

The result showed that there was a difference to students' understanding that learned with the previous and spiral curriculum. So, it can be concluded that the modified spiral (two-cycle) organic curriculum has positively impact to the students' understanding of Organic Chemistry I course.

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