Enhancing student problem solving skills through worksheets-assisted problem-based learning

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Abstract. This study aims to apply worksheets-assisted problem-based learning in Organic Chemistry I course and analyze its impact on student problem solving skills and learning outcomes. Subject of this study was 32 students from Chemistry Education Study Program who took organic chemistry 1 course. This classroom action research was conducted in three cycles. Each cycle consisted of four stages: plan, enact, observe, and reflect. Topics learned in this course included nomenclature, physical properties, synthesis and chemical reactions of certain organic compounds. Research instruments were problem-solving rubrics, observation sheets, and test questions. Problem-based learning syntax includes orientation on problems, defining problem, gathering facts, formulating questions, developing temporary answers, conducting experiment, reformulating problem, creating alternative solutions, suggesting proper solution, and class discussion. Findings show that students’ problem solving skills and their learning outcomes increased from cycle to cycle. Their problem solving skills in the first, second, and third cycles were 2.7, 3.1, and 3.6, respectively, while their learning outcomes in those cycles were 53.9, 72.1 and 74.5, respectively. Although there are still shortcomings with this study, we encourage other lecturers to implement this type of learning model in other courses or subjects in order to improve students’ problem solving skills.

1. Introduction
Organic Chemistry I studies nomenclature, structure, and synthesis reaction of certain compounds both on small-scale and large industries. Almost all reactions in organisms involve organic substances. It is impossible to be able to understand processes in living things without having knowledge of organic chemistry concepts. Students must comprehend atomic structure, chemical bonding, structure and physical properties, and also acid-base in order to study this subject successfully and all of those topics are learned in the Basic Chemistry I and II courses.

Organic I Chemistry learning is usually carried out through lectures and assignments like preparing papers for a certain subtopic of this course. Students generally utilize books or information from the internet as a reference for writing. Then, the paper is presented in front of class and other students can ask questions related to the content. Paper presentation is a confirmation activity that the information obtained does not conflict with that possessed by other students. In other words, students are mutually related to a particular concept and lecturer positions himself as a facilitator or mediator for learners.

The weaknesses observed so far that students used many outdated books as the source of writing this paper and some of them used ineligible information came from the internet. The discussion of
concepts was less profound and not even more than those contained in lecture notes or textbooks. Students only transferred information from textbooks and were lack understanding of the preparation process and organic reaction mechanisms. They were also less confidence when presenting papers because they did not comprehend the material and often cannot answer questions from other students, especially those related to organic reaction mechanisms. Learners as a source of information for other students were less useful. They discussed certain concepts through papers which turned out to be less mastering the material. They just waited and more trusted lecturer's explanation than their friend's description.

The lecturer still plays a central role in explaining a particular concept. He dominates learning process and students record lecturer’s explanation. As a result, direct instruction method cannot be abandoned. Learning is more focused on pouring knowledge to students ("tabula rasa" theory) and provides limited discussions. This conditions lead to passive learning. Students only listen to explanations and re-record concepts, especially those written by lecturers on the board. This kind of learning is preferred by students because they tend to memorize concepts and principles that have been taught. As a consequence, students easily forget the concepts and principles because they learn less meaningfully.

Real world contextual problems are expected to help students learn more meaningfully but they have not even been unable to solve this problem properly. Their answers or solutions tend to be partial and one and another concepts are not connected. Even, some of them experience misconceptions. The findings show that many students suffer misconceptions about many basic chemistry concepts like heat and temperature [1]. Only few students are able to answer conceptual and open-ended questions [2], which are characterized as unstructured and open-ended issues. Student problem solving skills affect learning outcomes. Most students attained C for Organic Chemistry I subject in 2009/2010 academic year. The main drawback was that students cannot explain the mechanism of organic reactions well and lacked of mastering concept in depth. Discussion and paper contents were mostly based on lecture notes or textbooks. Presentation was less prepared showing that student motivation was still low. The number of students who asked questions and gave responses during discussion was still limited. Reference used for any paper mostly came from rough source books. All of these problems indicate that learning has not touched motivation, problem solving skills, and student learning outcomes. Organic Chemistry I learning needs to be reoriented to increase motivation, problem solving skills, and student learning outcomes.

Learning must be student-centered with an emphasis on the relationship between content and context meaning that teaching materials must be related to problems that exist in students' daily lives. Reorientation of learning must use contextual problems, develop problem solving skills with the ability to argue and communicate concepts reliably, provide opportunities for students to reinvention, build independence in learning concepts, practice way of thinking and reasoning in drawing conclusions through investigation, exploration, experimentation, etc, enhance the ability to think imaginatively, intuitively, predictively and inventively through divergent and original thinking, use modeling, and accommodate differences in each student's characteristics.

Learning paradigm changing is not only about curriculum content, but also pedagogy. Lecturer can manipulate learning method in order to improve students’ learning performances like applying Flipped Classroom design [3]. Rutherford and Ahlgren, 1990 in [4] told to participants of Science for All Americans seminar, Project 2061:

"Students should be given problems-at levels appropriate to their maturity-that require them to decide what evidence is relevant and to offer their own interpretations of what the evidence means. This puts a premium, just as science does, on careful observation and thoughtful analysis. Students need guidance, encouragement, and practice in collecting, sorting, and analyzing evidence, and in building arguments based on it. However, if such activities are not to be destructively boring, they must lead to some intellectually satisfying payoff that students care about".

Students need authentic learning experiences and problem solving skills to handle unstructured problems. Al-Mubaid [5] states that a mental process that involves a high level of thinking for
problem-solving and decision-making is called as critical thinking. Critical thinking is a complex process that involves three crucial components, namely analyzing, assessing, and improving [6]. Critical thinking is needed in order to solve a problem with appropriate results.

One of principles of science learning is an active process [7]. This principle implies that science learning should be student-centered. Students identify problems, propose ways to solve problems, and then examine the proposed method. Students must be given physical experiences as a basis for developing abstract ideas. Active processes have mental and physical implications. Students must have hands-on and minds-on experiences. Learning must involve students in inquiry-oriented activities.

Learning is basically a meaningful process to achieve competence or life skills. Therefore, learning is an activity to shape, develop, and improve life skills. Only those who have life skills can survive and make their lives more meaningful. The meaning of life takes place in context. Therefore, learning will be meaningful if learning materials are associated with the real-world issues.

Contextual learning connects lecture material with student's real-world situation (context) and encourages students to make relationship between prior knowledge and its application in their daily lives as a family member and society. Contextual learning is based on the premise that the meaning of learning will emerge from the relationship between content and context. Context gives meaning to content [8]. Thus, learning that is in line with the above expectations is problem-based learning. Problem-based learning uses authentic problems, which are related to the social context [4]. Dewey in [9] believes that lecturers should teach by involving students' natural instincts to conduct investigation.

In problem-based learning, issues are learning stimuli [10]. Students face problem solving situations in small groups guided by tutors. Tutors help students in groups identifying the knowledge needed to solve problems by asking questions and monitoring the problem solving process [11]. Students conduct research to obtain data in order to solve problems with the help of tutors. Therefore, this study aims to apply worksheets-assisted problem-based learning in Organic Chemistry I course and determine the profile of students’ problem solving skills and analyze its impact on learning outcomes.

2. Methods
Subject of this study was 32 students from Chemistry Education Study Program taking Organic Chemistry I course. This classroom action research developed by Kemmis & McTaggart [12] was conducted in three cycles. Each cycle consisted of four stages: plan, enact, observe, and reflect. Each cycle contained 2 meetings and the duration was 150 minutes for each. Topics learned in this course included nomenclature, physical properties, synthesis and chemical reactions of certain organic compound.

Planning stage consisted of developing instructional materials and research instruments: observation sheets, rubrics, questionnaires, and test questions. Problem-based learning was implemented in action step including student orientation on problems, defining the problem, gathering facts, formulating questions, developing temporary answers, conducting experiment, re-formulating the problem, proposing alternative solutions, suggesting proper solution, and class discussion. There were three indicators observed in this study namely student and lecturer activities, students’ problem solving skills and learning outcomes. Reflection stage was intended as a step to control the quality of learning and at the same time analyze the development trend of student performance in solving contextual problems. Also, it was purposed to find out the weaknesses of the implementation of problem-based learning in each cycle, to determine corrective steps, and to know the achievement which will be maintained or improved in the next cycle. Design of this study can be seen in figure 1.
Data related to student problem solving skills were gained from student worksheets assessed using rubrics. The scores for the whole groups were summed then divided by the number of groups to get the average score of the class of problem solving skills. Student learning outcomes were determined from the total score of test result of all students divided by the number of students. The mean score of each cycle was compared and presented in table to determine an increase in student problem solving skills and learning outcomes. Student and lecturer activities in problem-based learning were observed utilizing observation sheet consisting of twelve aspects. The data obtained during the study were analyzed qualitatively and quantitatively. Qualitative descriptive analysis was used to analyze the development of students’ problem solving skills, their activities in problem-based learning, and describe the strengths and the weaknesses of this learning model and student worksheets. Quantitative descriptive analysis will be employed to analyze data derived from rubrics, observation, and test. This study will be considered successful if average score of students' problem solving skills is at least classified as good (minimum mean score of 3.0 on a scale of 4) and average score of student learning outcomes is at least 70.0.

3. Result and discussion
The success of this class action research is determined by the score of students' problem solving skills, their activities in learning process, and learning outcomes. The average score of all indicators for each cycle can be seen in table 1.

Figure 1. Classroom action research design
Table 1. Students’ problem solving skills, their activities and learning outcomes scores for three cycles.

| Indicator         | Average Score |
|-------------------|---------------|
|                   | Cycle 1 | Cycle 2 | Cycle 3 |
| Problem solving skills | 2.7    | 3.1    | 3.6     |
| Activities in PBL  | 3.4    | 3.7    | 4.2     |
| Learning outcomes  | 53.9   | 72.1   | 74.5    |

Table 1 shows that students’ problem solving skills, their activities, and learning outcomes increase from cycle to cycle. However, a significant improvement was achieved in cycle 2. The low scores of problem solving skills and learning outcomes achieved by students in cycle 1 were caused by three factors: student previous learning habits, lack understanding of chemistry concepts, and duration in discussing problem. Students were accustomed to "chalk and speech" learning method. They just sat, heard lecturer’s explanation and waited for the assignment. This is called teacher-centered learning where lecturers tend to dominate the process and less develop students' reasoning ability. They tend to teach learners what to think not how to think. As a result, students encountered difficulties in mastering chemistry concepts especially chemical reactions.

On the contrary, an increase in all indicators in this research in the second cycle was due to extra time given to students to discuss problems provided in worksheets. Worksheets were distributed three days before learning for a particular subtopic so students have more time to gather information, learn concepts related to problems and discuss the issues. In addition, the lecturer encouraged learners to express their ideas or difficulties experienced in learning process. However, 22% of students attained score less than 60 because they cannot explain the type and mechanism of certain reaction inquired in worksheets. Moreover, they needed extended time to find information in different sources. Therefore, they were provided additional time to access facts from different sources like the internet and several organic chemistry book and also the worksheets were distributed a week before the lecture. As a consequence, scores of all indicators in cycle 3 were higher than those in cycle 2.

3.1. Students’ learning outcomes
Table 1 shows that student learning outcomes experienced a significant increase from cycle 1 to cycle 2 and a slight rise in cycle III. The improvements occurred in cycle 2 and 3 because of actions conducted after reflection to alleviate weaknesses faced in cycle 1. For example, providing more time to gather information or enhancing lecturer’s ability as facilitator.

The findings indicate that problem-based learning and student worksheet can improve student learning outcomes. This is reasonable because this learning model starts from ill-structured, open-ended [13] and authentic problems [14]. Students will not be able to solve problems before they gather information, discuss it, formulate solution, conduct investigations, and draw conclusions. They will experience intellectual maturation during this process which affects the improvement in their learning outcomes. Learners actively construct knowledge in problem-based learning [11], [15]. Knowledge is formed from related concepts which are shown as semantic networks (Bruning et al., 1995 in [11]). They act as experts or become architects of learning [13] and control learning process without much intervention from the lecturer. As a consequence, their learning outcomes will improve.

3.2. Students’ problem solving skills
Students were divided into 9 groups and then their problem solving skills were analyzed through students worksheets. Score of problem solving skills for each group in each cycle can be seen in figure 2.
In general, score of problem solving skills for each group improved from cycle to cycle except groups 2, 5 and 9 (see figure 2). Groups achieved lower scores in cycle 1 because they were not yet accustomed to this learning model and experienced difficulties in solving ill-structured, open-ended and contextual problems offered in worksheets. Furthermore, problem-based learning model encouraged students to study independently like determining the concept, gathering information through varied media, and finding solution for a certain problem appeared in the worksheets and the lecturer did not explain the topic in advance.

In contrast, this score increased significantly in cycle 2 and continued to rise slightly in cycle 3. Additional action applied in the second and third cycles can overcome weaknesses in cycle I. Students already could explain the type of chemical reactions and its mechanism to yield a particular product. They also got used to solve an ill-structured, open-ended, and contextual issue which can develop their problem solving skills. Students were able to solve problems systematically started from defining problems, gathering information, restating problems, generating alternatives, suggesting solutions and providing recommendations [13]. Also this contextual issue can also prepare students to handle problem in their real life. Moreover, this learning model will develop creative thinking, one of the high level thinking skills [16] which is one of life skills that students should have in dealing with real-world. Students conduct analysis, synthesis and evaluation in depth. They can determine a credible source of information, analyze arguments, evidence, or facts, distinguish between facts and issues, do clarification, consider the implications of the chosen solution. As a result, they will be a good critical thinker and decision maker through this condition.

Yet, the scores for group 2 in three cycles were fluctuate while students in group 5 attained the same score in all cycles. On the other hand, group 9 had the same score in the first two cycles and then this score raised in the last one. These groups encountered matters in problem-based learning specifically in solving ill-structured, open-ended, and contextual problems. They had poor comprehension related to chemical reaction mechanisms for organic compounds and just mentioned chemical processes in general. They were only provided incomplete information related to real-world phenomena. As a result, they confused in deciding proper solution because learners usually face well-structured and closed-ended problems. For example: "State the stages of chemical reactions that occur in the process of producing alcohol!" or "What conditions should be considered in the process of producing alcohol?". In addition, these groups needed more time compared to others in discussion stage.
3.3. Student and lecturer activities

Organic Chemistry learning processes in three cycles were observed utilizing observation sheets. This instrument consists of twelve aspects namely (1) systematic presentation of subject matter, (2) encouraging students in discussion, (3) facilitating students to ask questions, (4) providing service in solving problems, (5) directing discussion process, (6) accuracy in using learning tools, (7) student collaboration, (8) student learning motivation, (9) student learning responsibilities, (10) student active participation in learning, (11) student interaction, and (12) peer tutoring activities. Lecturer activities (aspects 1-6) and also learners' (aspects 7-12) were observed utilizing this instrument. Score for each aspect can be seen in figure 3.

Figure 3 shows that problem-based learning provides an opportunity for the lecturer to act more as a facilitator, mediator, and meta-cognition trainer for students in order to design an effective, efficient, creative and innovative organic chemistry learning. The lecturer had already presented the subject systematically and tried to encourage learners to express their opinion or questions in small group discussion. She got familiar with this learning model revealed from her activeness in the first six aspects in three cycles. Similarly, students were more and more active in chemistry lesson from cycle to cycle especially in collaborating with others and participating in problem-based learning. Problems provided in worksheets can motivate students to be actively involved in learning [9], [17]. They can identify and solve the problems with their own ideas and abilities and develop their creative thinking [16] to determine real issues. In addition, they can correlate topics with real life, develop their reasoning, and improve their understanding of chemical concepts. Real-life issues could help learners relate lesson to daily life and increase their motivation in learning chemistry [18].

This study also finds that student interaction and oral communication skills improved because they can express their opinions or ask questions. They were involved in sharing ideas to obtain the best solution. Working in small groups allows students to develop communication skills. Czujko, 1994 in [19], [20]. Also, problem based learning can improve learning responsibilities and create enjoyable learning [20]. This condition also encouraged peer tutoring activities. They work with their peers to have an appropriate solution to overcome issues. Students can utilize their problem-solving methods and conceptual knowledge through working in small groups [15].
4. Conclusion
Problem-based learning can improve students’ problem solving skills from 2.7 in cycle 1 to 3.6 in the last cycle. Also, their learning outcomes in the first, second and third cycles are 53.9, 72.1 and 74.5, respectively.

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