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THE ELABORATION OF UNDERSTANDING BY DESIGN IN A PHYSICS LEARNING ABOUT CAPACITOR CIRCUITS

Yerika P. Rosanti[1a)], Debora N. Sudjito*[1,3b)], Ferdy S. Rondonuwu[2,3]
[1]Department of Physics Education
[2]Department of Physics
[3]Research Center of Science, Technology, and Mathematics (e-SisTeM)
Faculty of Science and Mathematics, Universitas Kristen Satya Wacana,
Jl. Diponegoro 52-60, Salatiga, Indonesia (0298) 326-421121
e-mail: [a)]yerikapuspa@gmail.com, [b)] debora.natalia@staff.uksw.edu

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ABSTRACT

The connection among learning objectives, learning evaluation, and learning steps in a lesson plan is essential in an effective learning. A meaningful learning to students is a learning where learning objectives, evaluations, and steps are interrelated. A physics learning about capacitor circuits is an abstract learning that requires the proper learning method so that students can easily understand it. The purpose of this study is to make a lesson plan about capacitor circuits using UbD. Understanding by Design (UbD) is often referred to as "Backward Design" – an alternative lesson plan in a sequence namely learning objectives, learning evaluations, and learning steps. First of all, the lesson plan was made about capacitors using UbD Template. The lesson plan then was given to the three reviewers who are all physics teachers. Suggestions from reviewers will be reviewed and used as a reference in the improvement or revision of the lesson plan.

Keywords: Understanding by Design, capacitor circuit, physics learning

INTRODUCTION

The connection among learning objectives, learning evaluation, and learning steps in a lesson plan is essential in an effective learning. However, in general, the implementation of Physics learning often focuses on textbooks and learning activities without regard to the objectives to be achieved so that learning objectives are made in such a way as to accommodate all the material (Wiggins, 2005). This is referred to as content-focused design. Teachers who apply content-focused design usually base their learning process on a particular topic from the textbook. Even though the textbook should be used to improve the efficiency and effectiveness of learning, the way the material taken from the textbook must be adapted to the needs of students (Wiggins, 2012). In addition to the problem of how to use the textbook effectively, the learning method that is done is less creative, that is only in the form of lectures, discussions, reading books, and the learning focus is only on memorizing formulas (Wiggins, 2012). As a result, students are not interested in the learning and they do not understand why they should learn the material. Teachers do not tell students the learning objectives and how they will be evaluated. Evaluation questions are generally made at the end (before the test), and then they are only copied from the textbook to find out students' understanding of the book without adjusting to the learning objectives and the learning steps that have been taken. As a result, their evaluation scores are poor. Based on this illustration, it appears that it is unfair for the

students if they do not know why they must learn a material and then they are assessed by certain evaluation instruments, but they are not equipped with sufficient knowledge and ability to do it. In addition, improving the quality of learning through the presentation of meaningful learning must be fulfilled by the teacher. Thus, the lesson plan must really be concerned so that the learning becomes meaningful.

The teacher is the designer of a meaningful learning for students when the designed objectives, evaluations, and steps of learning are interrelated. To present a meaningful learning for students and to provide material coverage that is suitable for the needs of the students, a lesson plan is needed to allow the teacher to see the relevance of the objectives, evaluations, and the steps of learning that he/she designs. An alternative lesson plan that can be used is Understanding by Design (UbD).

Understanding by Design (UbD) is a result-focused design (understanding-based) to eliminate a design-making habit that focuses on activity-based steps and a design that focuses on the textbooks (coverage-based). At the activity-based design, the teacher focuses on the learning activities that will be carried out (Wiggins, 2005). Unfortunately, they make activities that are very interesting and fun, but not related to the existing material and they do not achieve the objectives of the learning itself. Such learning usually happens in the elementary and middle schools. In coverage-based, the teachers are fixated on the textbook (Wiggins, 2005). They only teach what is in the book, and keep following the book without emphasizing on students' understanding or important points from the learning so that students easily forget the material of the learning. In addition, if teachers follow the textbooks, mostly they will not adjust the time allocation that is available, thus, they do not have time to practice applying the learning. Such learning is usually done in high schools and lectures.

UbD is applied as an alternative solution to improve the quality of learning by synchronizing learning objectives, steps, and evaluations. UbD helps to focus learning on student understanding and streamlines the transfer of knowledge and abilities from teachers to students (Wiggins, 2012), so that students will not easily forget it and later the material can be used again in different circumstances (building a concept map in students' minds) (Wiggins, 2011; Yurtseven, 2016). UbD also helps teachers to create learning systems that focus on achieving learning objectives that are assessed through evaluation of interrelated and supporting learning (Wiggins, 2012; Wiggins, 2011; Almasaeid, 2017) so that maximum value can be obtained. UbD is also referred to as *Backward Design* (Wiggins, 2005). In general, the design of learning by the teacher starts from the learning objectives – the learning step – learning evaluation; whereas in UbD, evaluation design and learning steps are reversed so that the design sequence becomes learning objectives – learning evaluation – learning steps. There are three stages in UbD. Stage 1 contains learning objectives. Stage 2 contains learning evaluations. Stage 3 contains learning steps.

This study highlights the interrelationship of objectives, evaluation, and learning steps of basic physics about capacitors. This material is chosen because it is one of the basic materials in Physics in which most of the concepts cannot be observed directly so that it may cause misconceptions (Wiggins, 2012). Based on interviews with students and lecturers about the learning of capacitor circuits, there were some difficulties faced by the students in the learning. The first difficulty was the difficulty of assembling electrical components because they did not understand the relationship between the components. They could not distinguish series and parallel arrangements because they did not understand the characteristics of series and parallel circuits. The second difficulty was that they did not understand the meaning of quantities in capacitor circuits since these quantities are abstract.

They had a difficulty analyzing these quantities, both to measure and to calculate.

The purpose of this study is to make an alternative lesson plan about series and parallel circuits on capacitors using UbD intended for Basic Physics course for the first year students. The benefits of this study is that it will be an example of how to make lesson plans using UbD which has been adapted to the Indonesian education context.

RESEARCH METHODS

First of all, the lesson plan was made about capacitors using UbD. The UbD template can be seen in Table 1. The template used in this study is different from the UbD template created by Grant and Wiggins. The template in Table 1 is the result of simplification by taking the main parts of the original template and adjusting to the educational context in Indonesia. UbD is a design that is originally implemented in western world education so that it is simplified in order to adjust to the teachers in Indonesia.

There were 3 stages in UbD. Stage 1 contains learning objectives. The learning objectives contain targets to be achieved through the learning steps and must be evaluated. Making objectives began with the determination of key points or key concepts that were targeted to be achieved by taking into account the competency targets of study program. For that reason, in formulating the learning objectives, teachers must first understand the topic carefully so that they can determine the learning objectives that are expected to be achieved by students. Sometimes, there is a lot of material in the curriculum even though the time available is very limited. Therefore, the teacher must be smart at sorting and managing the priority of the material. Once the main concept is obtained, the learning objectives are made based on the key concept assumptions. Objectives are made in such a way that they can be evaluated.

Tabel 1. UbD Template Adjusting to the Educational Context in Indonesia

STAGE 1 – Desired Results
1. …… 2. …… 3. Etc
STAGE 2 – Assessment Evidence
Assessment: 1.1 …… 1.2 …… Learning Evaluation: 1.1.1 …… 1.1.2 …… 1.2.1 …… 1.2.2 ……
Assessmet: 2.1 …… Learning Evaluation: 2.1.1 …… 2.2.1 ……
And so on until the last assessment and evaluation. Each goal can have several assessments and each assessment can have more than one evaluation. Assessments and evaluations are colored in the same color as the goal.
STAGE 3 – Learning Plan
Time allocation :
• Learning step 1 • Learning step 2

Stage 2 contains learning evaluations – evidence of the achievement of learning objectives at Stage 1. This step began with formulating an assessment of learning. In this case, the teacher must "think like an assessor". Assessment is made by taking keywords in the learning objectives so that they relate to the learning objectives by paying attention to the following questions (Wiggins, 2005): (1) How do we know that students have successfully answered the learning objectives? (2) What can be the proof that the objective has been achieved? and (3) Can the evidence guarantee that students have understood the material? After the assessment, evaluation questions were made. The learning evaluations were not made or only copied from books or the internet, but they were made based on the assessment formula. The form of learning evaluation can be in the form of an oral test or question-answer format in the classroom when learning takes place, observation, written quizzes/tests, or projects or practicum. The questions of evaluation are not limited in number depending on the needs of each teacher. Questions and instructions on evaluation were made using open sentences that are interesting and challenging as well as clear and easy to understand.

Stage 3 contains learning steps. At this stage, the method that would be used was designed in advance. The selection of improper methods can influence the effectiveness of learning and the quality of understanding of students (Hesti, 2017) so it is very important to choose a method that is suitable for the material being taught and in accordance with the available time allocation. If the learning goal is assumed as a tourist or travel destination, the learning step is the process of our journey to get there. Before we go to a destination place, we must first make a plan. This is related to the path chosen, time efficiency, and equipment that must be carried. Likewise, it also applies in making learning steps. Teachers must pay attention to the allocation of available time, choosing an efficient and effective learning method to teach the material, choosing appropriate books/learning resources, and preparing points that must be emphasized in learning. In addition, through the learning steps students must be able to do the evaluation given. Thus, in making the learning steps, students must also pay attention to the evaluation of learning.

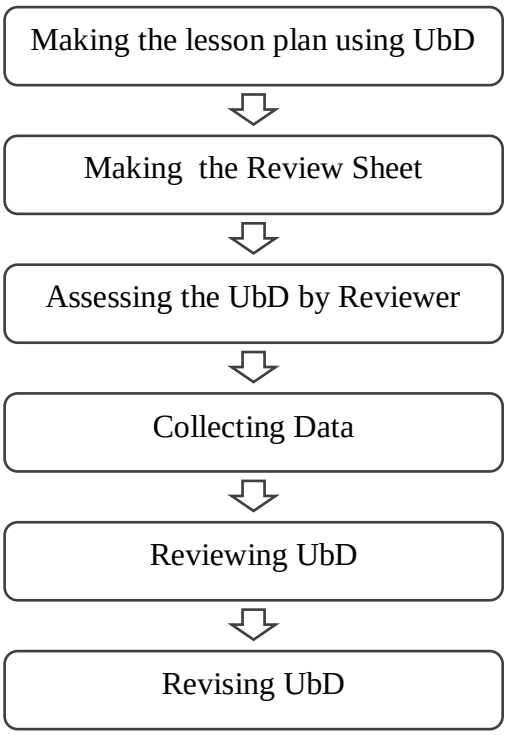


Figure 1. Structure of UbD Elaboration

The study continued with the creation of a review sheet that would be used by the reviewer to review the UbD. The review sheet used in this study is in the form of a multilevel scale, in which a statement followed by a column that shows the scoring levels with a scoring scale that matches the predetermined criteria and the response column. The statements in the review sheet are suitability of evaluation with learning objectives, suitability of learning steps with learning objectives, suitability of evaluation with learning steps, suitability of learning methods with material, depth of material, effectiveness of media and learning methods, time allocation, and effectiveness and clarity of writing instructions on evaluation and learning steps. The questions on this review sheet were summarized from the key points of UbD to show the advantages of UbD,

namely the relation among objectives, evaluation and learning steps, not only in general but also in detail.

The lesson plan then was given to the three reviewers who are all physics teachers. The reviewers reviewed the lesson plan using the guidelines in the review sheet. The data obtained from the review sheet were then analyzed in a qualitative descriptive method. Suggestions from reviewers will be reviewed and used as a reference in the improvement or revision of the lesson plan. The entire research procedures can be seen in Figure 1.

RESULT AND DISCUSSION

Based on the existing background, a lesson plan was developed in this study using Understanding by Design (UbD). The UbD in this study was made for Physics learning about series and parallel capacitors for the first year students. At Stage 1, 3 learning objectives were made for series and parallel capacitors, such as (1) students could distinguish characteristics of series and parallel circuits; (2) students could arrange circuits of series and parallel capacitors; and (3) students could analyze physical quantities in the capacitor circuits. These objectives would be the main points in making of the capacitor circuits, which underlies all materials of capacitor circuits. The purpose of this learning is made with clear sentences and the achievement can be measured.

Stage 2 contained evidence showing the success or the achievement of the learning objectives in the form of learning evaluations. Before making evaluations, assessments were first made. These assessments were derived from the learning objectives and then appropriate evaluation questions were made. There were 4 assessments made on this UbD, namely (1) students could assemble the components provided in accordance with the series drawings and in accordance with existing provisions, (2) students could install meter and voltmeter capacitances correctly, (3) students could measure substitute capacity and voltage between two points, and (4) students could calculate substitute capacity, voltage, and electric charge between two points.

Six evaluation questions were made of the four assessments. To work on evaluation questions number 1-3, the students were first given a mixed circuit drawing. They were asked to assemble the electrical components available according to the drawing. From that circuit, they were asked to calculate and measure the physical quantities (capacitor capacity, electric charge, and voltage). The circuit used was simple series in which application can be seen in everyday life so that it will be easier for the students to imagine. In problem number 1, they were asked to measure and calculate the substitute capacity between two points in the circuit. In problem number 2, they were asked to measure and calculate the voltage between two points in the circuit. In problem number 3, they were asked to calculate the electric electric charge between two points in the circuit. Furthermore, in question number 4-6, they were asked to choose the correct components to be assembled in a simple capacitor circuit so that the total capacity and total load are in accordance with the provisions given by the teacher.

These questions were made to evaluate the three learning objectives. The first and second objectives were said to be achieved if the students could arrange the sequence appropriately in accordance with the existing diagram or in accordance with the provisions given because in order to assemble a mixed series, they must first understand the relationship between components, whether component A was arranged in series or parallel with component B, and whether component B was arranged in series or in parallel with component C, etc. That analysis was considered to assess the achievement of the first objective. If they could assemble the sequence appropriately, it could be said that they understood the differences in series and parallel circuits and in this case, the relationship between the components.

In addition, the first objective could also be achieved if the students could calculate the magnitude of the circuit correctly, because there were different ways of calculating quantities in series and parallel circuits. The capacity calculation between two points in series and parallel circuits in capacitors had different equations. Furthermore, the voltage and electric charge characteristics of these two circuits were also different. In a series circuit, the voltage in each capacitor was different but if it was summed, the value would be equal to the total voltage in the series; whereas in parallel circuits, the voltage in each capacitor was equal. In addition, the electric charge on each capacitor arranged in series had the same value; although the electric charge varied in the value but if it was added the value, it was equal to the total electric charge of the parallel circuit. Therefore, if the students could calculate exactly the three quantities, it could be said that they understood the differences between the two sets so that they could prove the achievement of the first objective.

The third learning objective was said to be achieved if the students could measure and could calculate the physical quantities in the evaluation questions.

The final step was to make learning steps. In this UbD, learning was carried out with two methods, namely lecture and practicum. Lectures were carried out first to review the physical quantities and equations of the series and parallel capacitor circuits that had been obtained by students beforehand. The equations in the series circuit were:

$$\frac{1}{C_{total}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_s} + \cdots + \frac{1}{C_n} \quad (1)$$

$$V_{total} = V_1 + V_2 + \cdots + V_n \quad (2)$$

$$Q_{total} = Q_1 = Q_2 = \cdots = Q_n \quad (3)$$

Equations in parallel circuit were:

$$C_{total} = C_1 + C_2 + C_3 + \ldots + C_n \quad (4)$$

$$V_{total} = V_1 = V_2 = \cdots = V_n \quad (5)$$

$$Q_{total} = Q_1 + Q_2 + \cdots + Q_n \quad (6)$$

Then the learning was continued by practicing. This is also discussed by Orlaineta (2017) in which to study the magnitude in an electrical circuit, it will be suitable to use a method of active learning because active learning requires students to take part in learning and it becomes an experience for students. Electrical circuit material is an abstract concept and it is a confusing material for students so that the practicum method is chosen, with the aim that students can get visualization from the material and they will understand the learning more easily. At the beginning of the practicum, the students were divided into several groups and each group was given a Practicum Worksheet. There were three practices that must be done by students namely, practicum of series circuits, parallel circuits, and mixed circuits. In the series circuits practicum, students were asked to assemble a series of 3 capacitors connected to the voltage. After that, they were asked to measure the capacitance and voltage of each capacitor, to measure and calculate the total capacitance and voltage of the circuit, and to calculate the electric charge on each capacitor and the total electric charge of the circuit and then to enter the results in Table 2.

Table 2. Practice Results of Series Circuits

Capacitor	Capacitance (µF)		Voltage Measurement (V)	Electric charge Calculation (C)
	Measurement	Calculation		
C_1				
C_2				
C_3				
Total				

In parallel circuit practicum, the students were asked to assemble a parallel circuit of three capacitors connected with a voltage. Then, they were asked to measure the capacitance and voltage of each capacitor, to measure and calculate the total

capacitance and voltage of the circuit, and to calculate the electric charge on each capacitor and the total electric charge of the circuit and enter the results in Table 3.

Table 3. Practicum Results of Parallel Circuits

Capacitor	Capacitance (µF)		Voltage	Electric charge
	Measurement	Calculation	Measurement (V)	Calculation (C)
C_1				
C_2				
C_3				
Total				

In mixed circuit practicum, the students were asked to assemble a mixture of 5 capacitors (shown in Figure 2). Then, they were asked to measure the capacitance and voltage of each capacitor, to measure and calculate the total capacitance and voltage of the circuit, and to calculate the electric charge on each capacitor and the total electric charge of the circuit and enter the results in Table 4.

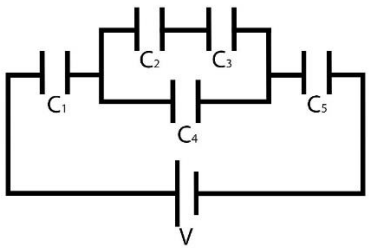


Figure 2. Mixed circuit practicum

Table 4. Practicum Results of Mixed Circuit

Capacitor	Capacitance (µF)		Voltage	Electric charge
	Measurement	Calculation	Measurement (V)	Calculation (C)
C_1				
C_2				
C_3				
C_4				
C_5				
Total				

This practicum was carried out to answer all three objectives. At the end of the practicum, the students were asked to write down the conclusions from the practicum. Through practicum, it is expected that they can get more experience because in the implementation they must think more critically. In addition, they also have the opportunity to try and correct their own mistakes. This learning step trains them to achieve cognitive ability competence in taxonomy bloom, namely remembering (C1), understanding (C2), applying (C3), and analyzing (C4), and concluding (C5).

Based on the results of the review, there were several suggestions submitted by the reviewers. At Stage 1, reviewers recommended changing the order of the first and second learning objectives. Learning objectives should be written sequentially, starting from the goal to be achieved in the beginning until the last goal that would be achieved. This suggestion was accepted so that the learning objectives were in order. The students learned the characteristics of the circuit and also through the practice of arranging the circuit so that the order of the two objectives was reversed. Changes that have been made on the learning objectives can be seen in Table 5.

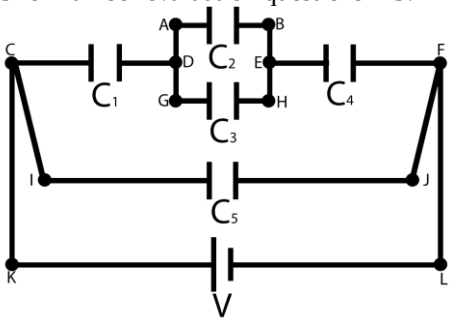
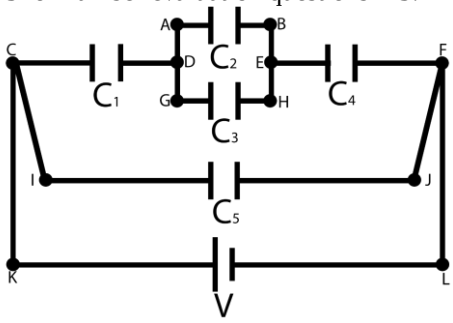
Table 5. Results of Improvement of Learning Objectives

Before corrected	After corrected
1. Students could distinguish the characteristics of series and parallel circuits.	1. Students could arrange circuits of series and parallel capacitors.
2. Students could arrange circuits of series and parallel capacitors.	2. Students could distinguish the characteristics of series and parallel series.

3. Students could analyze physical quantities in capacitor circuits.	3. Students could analyze physical quantities in capacitor circuits.

At Stage 2, according to the reviewers, the evaluations were made in accordance with the learning objectives and could be used as a benchmark for achieving the learning objectives. However, sentences on the evaluation questions were not clear. In the evaluation questions 1-3, the students were asked to assemble electrical components in accordance with the drawing provided and then to measure and calculate the capacity, voltage, and electric charge in the circuit. These questions were made to evaluate the first and third learning objectives, namely to arrange circuits and to analyze the quantities. However, there were no sentences indicating that the students must assemble their own circuits so that an improvement was needed in the sentence about evaluation numbers 1-3. This suggestion was accepted so that instruction could be more easily understood. Changes made to the learning evaluations can be seen in Table 6.

Table 6. Results of Improvements to Learning Evaluation

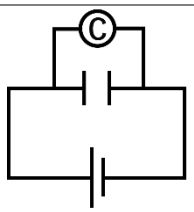
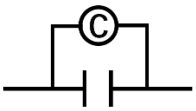
Before corrected	**After corrected**
Figure 3 for number evaluation questions 1-3:  $C_1= C_2= C_3= C_4= C_5=10\ \mu F$ V=1,5 V	Figure 3 for number evaluation questions 1-3:  $C_1= C_2= C_3= C_4= C_5=10\ \mu F$ V=1,5 V
1. Measure and calculate the amount of substitute capacity between points: a. A and B b. C and E c. C and F d. K and L	1. Arrange the components according to the drawing above, then measure and calculate the amount of substitute capacity between points: a. A and B b. C and E c. C and F d. K and L
2. Measure and calculate the voltage between points: a. G and H b. D and E c. D and F d. K and L	2. Based on the circuit on problem number 1, measure and calculate the voltage between points: a. G and H b. D and E c. D and F d. K and L
3. Calculate the amount of electric charge between points: a. A and B b. C and E c. I and J d. K and L	3. Based on the circuit on problem number 1, calculate the amount of electric charge between points: a. A and B b. C and E c. I and J d. K and L

At Stage 3, the reviewer considered that the learning steps taken were good. These learning steps could support the achievement of learning objectives and could be evaluated with evaluation questions made. Lecture learning method

was regarded to be effective to be used in reviewing capacitor circuit material that students had previously learned. Practical learning methods, which were the core of learning, were considered to be very suitable with this material and were very helpful to help students to understand the learning of the circuits.

However, the depth of material will not be suitable if it is taught for first year students. Reviewers recommended adding more material to this UbD. Physical quantities in the capacitor circuit are not just capacitance, voltage, and electric charge, so to answer the third learning objectives, evaluations and learning steps, it needs to be added with the analysis of other physical quantities. This suggestion was accepted because it suited the learning objectives. Other physical quantities were added to the capacitor circuit, namely stored energy, physical field between capacitor chips, and dielectric constant, which both were in the learning steps and the learning evaluations. In addition, another thing that needed to be changed was the installation of capacitance meter. The image of the capacitance meter must be changed considering that the capacitor was useful for storing the electric charge so that the measurement needed not to be connected to a voltage source as shown in Table 7.

Table 7. Results of Improvements to Learning Steps

Before corrected	After corrected
 **Figure 3.2. Installation of Capacitance Meter**	 **Figure 3.2. Installation of Capacitance Meter**

The UbD design will help to link learning objectives, learning evaluations, and learning steps to improve student comprehension. Yurtseven (2016) also said in his research that designing a learning with UbD will also increase transfer skills of students' knowledge.

The result of another review is that the learning methods used are appropriate in accordance with existing materials and they are complementary; instructions on learning steps are easy to understand and can be done by students; a time allocation of 240 minutes is enough to complete the learning; and open question has been used for questions on evaluation problems.

CONCLUSION

Understanding by Design (UbD) is often referred to as "Backward Design" – an alternative lesson plan in a sequence namely learning objectives, learning evaluations, and learning steps. First of all, the lesson plan was made about capacitors using UbD Template. The lesson plan then was given to the three reviewers who are all physics teachers. Suggestions from reviewers will be reviewed and used as a reference in the improvement or revision of the lesson plan.

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