International Journal of Science and Applied Science: Conference Series P-ISSN: 2549-4635
Int. J. Sci. Appl. Sci.: Conf. Ser., Vol. 2 No. 1 (2017) E-ISSN: 2549-4627
International Conference on Science and Applied Science 2017 doi: 10.20961/ijsascs.v2i1.16666

Using Spreadsheet Modeling in Basic Physics Laboratory Practice for Physics Education Curriculum Undergraduate

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Abstract. Physics is one of a branch of science which uses much of mathematical concept. Usually, the concept of physics is expressed in a mathematical equation; it will make physics easier to be understood. Therefore, the students need to understand about mathematical modelling to help them understand physics. Students who take fundamental physics and physics laboratory course required to understand the concept of feedback that is mathematically expressed in differential equations. However, most of the students have not been taught the concept of differential equations at early semester. Therefore, we are interested in reviewing the use of mathematical modelling with a spreadsheet in the case of feedback that is integrated with laboratory practice. The results of this study indicate that students gave positive perceptions and improve their ability in understanding the concept of feedback that is mathematically expressed in the differential equation.

Keyword : modelling, spreadsheet, laboratory practice

1. Introduction

The important goals for physics education are the students mastered physics concept theoretically and used the scientific method to prove the theory. Therefore, in a physics course, the theoretical lesson should be followed by laboratory practice. In learning physics, especially at university level, the students should be involved to get the concept, the students not only hear the lecture or read from a textbook [1, 2]. Laboratory practice should be done to prove or to get the concept. Learning physics without laboratory practice can cause student's bad performance [3]. In laboratory practice, the students must do the experiment as best as possible and avoid something that disturbs their work. The quality of measurement depends on the data accuracy and precision. If the measured value is very close to real values, the data accuracy will be very high [4].

The laboratory practice is very useful in learning physics, especially to help students prove the concept. The modeling of physics phenomena by mathematic modeling cause more complicate d students to understand the phenomena. One of effort to help students to understand mathematic modeling is using computer that guide students to get a new knowledge [5]. Mathematical modeling using computer required to be taught in the classroom learning process because it can facilitate students to learn through simulation and visualization. Using computer simulation is one of the alternative ways to help students learning the scientific method such make the model,

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investigate the relationship between variables in the model, and use the model to answer the hypothesis [6]. It is considered that raising laboratory practice supported by computer is very important. Using computer simulation helps students to represent the model and do the computation. Therefore, the computer simulation can be used by the students to compare the real experiment and simulation.

Resistor and capacitor circuit (RC circuit) generally taught to students in a fundamental physics course . RC circuit is one of the example s of the dynamic system that mathematically stated as the differential equation. The characteristic of RC circuit often difficult for students. Most of the students who took the introductory physics course with traditional lecture instruction were unable to predict the behavior of a series circuit consisting of a battery, a bulb, and a capacitor [7]. Based on the previous researches, we try to integrate computer simulation use spreadsheet excel in laboratory practice. The computer simulation used spreadsheet modeling is expected can help students to predict the behavior of RC circuit that mathematically presented in the differential equation. In the simulation, we use spreadsheet excel because it can illustrate graphics on a screen and illustrate many physical processes, easy to use especially the students, make the lesson interesting, and contributes to the scientific and technological knowledge of the students [8,9,10].

The simplest RC circuit consists of a resistor, a capacitor, and a battery. The RC circuit is depicted in figure 1.

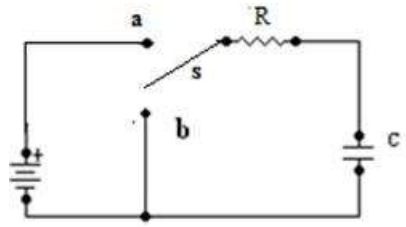

Figure 1. RC circuit with contact point a and b

Based on figure 1, charging capacitor occurs when the switch connected to point a and discharging capacitor occurs when the switch connected to point b. According to Kirchhoff's second laws, the relation between potential difference and current when charging capacitor process can be stated as

$$\varepsilon = iR + \frac{Q}{C} \tag{1}$$

using definition $i = \frac{dQ}{dt}$

equation (1) can be written as

$$\varepsilon = R\frac{dQ}{dt} + \frac{Q}{C} \tag{2}$$

the general solution of differential equation (2) is

$$Q = C\varepsilon\,(1 - e^{-\frac{t}{RC}}) \tag{3}$$

if $Q_0 = C\varepsilon$ the equation (3) become

$$Q = Q_0\,(1 - e^{-\frac{t}{RC}}) \tag{4}$$

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the current can be written as

$$I = \frac{dQ}{dt} = \frac{\varepsilon}{R} e^{-t/RC} \quad (5)$$

in discharging capacitor process, the relation between potential difference and current can be written as

$$iR + \frac{Q}{C} = 0 \quad (6)$$

$$R\frac{dQ}{dt} + \frac{Q}{C} = 0 \quad (7)$$

the general solution of differential equation (7) is

$$Q = Q_0 e^{-t/RC} \quad (8)$$

and the current can be write as

$$i = -\frac{\varepsilon}{R} e^{-t/RC}$$

using Euler method, the general solution of equation (2) can be written as

$$Q_{i+1} = Q_i + I_i \Delta t \quad (9)$$

where

$$I_i = \frac{1}{R}\left(v_i - \frac{Q_i}{C}\right) \quad (10)$$

using the same method, the general solution of equation (7) can be written as

$$Q_{i+1} = Q_i + I_i \, \Delta t \quad (11)$$

where

$$I_i = -\frac{V_i}{RC} \quad (12)$$

2. Methodology

The subject of this research were 59 students of the second semester of physics education department of Sebelas Maret University in the 2016/2017 academic year. In this semester, the students take the fundamental physics course . The course consists of theoretical class (3 credits) and laboratory class (1 credit). In class, the students study the concept theoretically, then they have to prove the concept in laboratory activities. In the laboratory, the students do the experiment by guiding the instruction sheet and lecture's assistance.

In this research, we develop laboratory practice using spreadsheet modeling in RC circuit topic. After taking the theoretical class, the students asked to make a simulation using the spreadsheet. Because students have not already taught how to solve the differential equation using an analytical method, we teach the students how to solve the differential equation using Euler method then do the computation in a spreadsheet environment. In the laboratory, the students must prove their simulation to the real experiment. We gave essay questions to assess the student's knowledge and interview to know the respond of students to this course.

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3. Result and Discussion

3.1. Result

At the beginning course, the students asked to describe the behavior of RC circuit refer to the differential equation. The example of the answer shown in figure 2 and 3. In figure 2 the students give an example the function y=x to express the differential equation y to x written as dy/dx. The answer from the other student shown in figure 3, they will detracting the power of variable and it's multiplied by the constant of the variable.

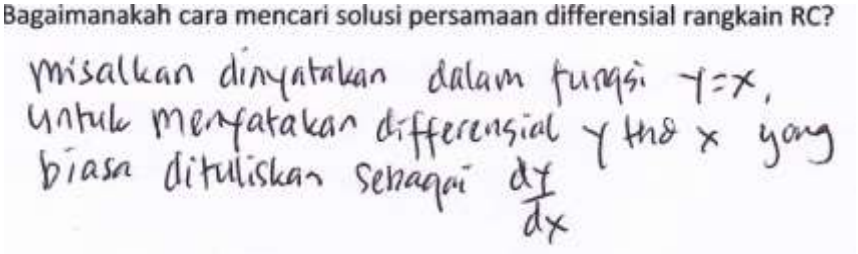

Figure 2. Snapshot of student's perception about differential equation as differentiation

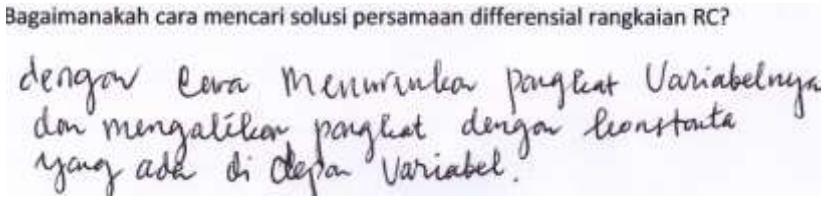

Figure 3. Snapshot of student's perception about solving differential equation use differentiation method

Based on figure 2 and 3, it can be concluded that the students do not understand the concept of the di fferential equation. In figure 2, the student miswrote the differential equation of RC circuit, they wrote dy/dy nor dQ/dt. According to figure 3, it can be concluded that the students thought that differential equation can be solved use differentiation method. The students were unable to describe the differential equation because they have not already studied the differential equation in a calculus course.

The focuses of this study were to train students how to solve the differential equation use Euler method and use spreadsheet excel to make the simulation. The spreadsheet excel is used to make simulation because the student already used spreadsheet excel to analyze the data of experiment. After students followed theoretical class about RC circuit, three students asked to do the experiment about RC circuit without make simulation before. The goal of this treatment is to know how students integrate the concept of RC gotten in class to do an experiment in laboratory practice. We found that the students do the experiment carelessly. The example of measurement report of discharge capacitor shown in figure 4.

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Tabel 1. Data Pengamatan Pengosongan Kapasitor

No	t (s)	V (volt)
1	5	8.82
2	10	6.31
3	15	3.3
4	20	0.5
5	25	2.18
6	30	1.36
7	35	0.73
8	40	2.3
9	45	0.17
10	50	0.13
11	55	0.12
12	60	0.097
13	65	0.098
14	70	0.36
15	75	0.99

Figure 4. An error in measuring data of discharging capacitor

Based on figure 4, it can be concluded that the students did not understand the concept of discharging the capacitor. The students just did the experiment without considering the behaviour of discharging capacitor that is taught in theoretical class. If the students understand the concept of discharging capacitor that represented by the differential equation, they will check that the voltage Vn > Vn+1 the students will repeat the laboratory practice until they get data that fulfill the criteria. According to the interview, it can be concluded that students did not consider the concept of discharging the capacitor when doing the experiment , they just followed the experiment instruction and used digital voltmeter carelessly.

After finishing the training of spreadsheet modeling use Euler method, all of the students asked to make simulation before performing the experiment. The students made a simulation of discharging and charging capacitor used spreadsheet modeling. They used Euler method as spreadsheet modeling. In the simulation, they used the same value of resistor, capacitor and power supply that will be used in the experiment. The example of simulation about discharging capacitor shown in figure 5.

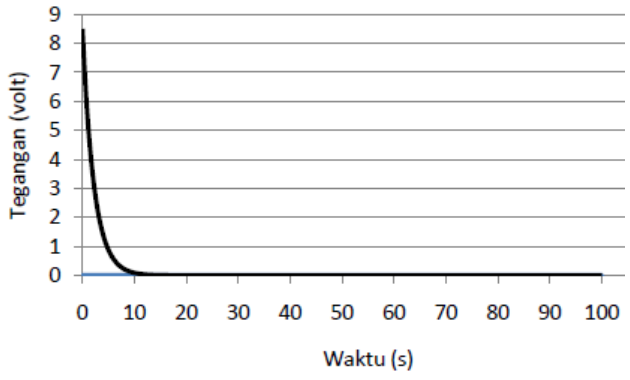

Figure 5. Snapshot of simulation of discharging capacitor used spreadsheet modeling

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After making the simulation, the students discussed the behavior of discharging a capacitor, they als o explored the effect of each variable to the behavior of the system. The example of data of charging and discharging capacitor got the students in laboratory shown in figure 6 and 7.

Tabel 2. Pengukuran V pengisian dan V pengosongan untuk R=4,7 k, C =470μF dan V=8,5 volt

t (s)	V pengisian (volt)	V pengosongan (volt)
10	8.16	0.0505
20	8.44	0.029
30	8.41	0.0101
40	8.45	0.006
50	8.44	0.0043
60	8.46	0.0034
70	8.47	0.0028
80	8.47	0.0024
90	8.47	0.0025
100	8.47	0.0021

Figure 6. Snapshot of experiment data of discharging and charging capacitor

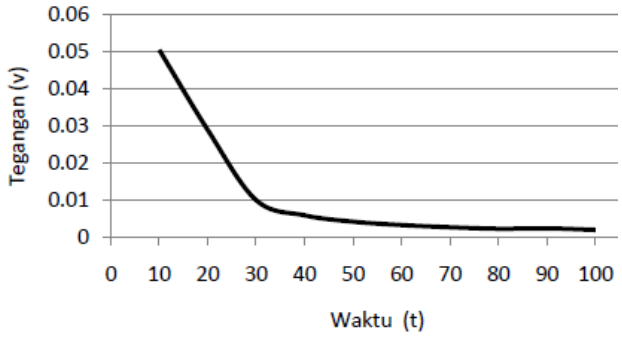

Figure 7. Snapshot the graph discharging capacitor used experiment data

The students used R = 4,7 kΩ, C = 470 μF, and ε = 8,5 volt in simulation used spreadsheet excel and laboratory experiment. In reporting the laboratory practice, the students compared the data based simulation and experiment. We found that most of the students just gave more attention to the experiment's data and ignored the simulation. They wrote that the experiment's data appropriate to the simulation after 10 seconds. It is just a few students analyze d the difference between simulation and experiment. According to the students, the data for less than 10 seconds is difficult to get because of the rate of change voltage is too fast, the data were stable after 10 seconds.

Based on the interview, it can be concluded that made simulation using spreadsheet modeling help students in doing an experiment. They said that the course was interesting. The students were able to do the experiment carefully to get data accurately and precisely. They said that use spreadsheet modeling helps them to solve the differential equation easier than using the usual mathematical method. The students said that they understand about Euler method, but they have a problem when writing the Euler method into a spreadsheet. In spite of students were familiar to use a

spreadsheet to analyze the experiment data, but most of them felt difficult to perform Euler method into a spreadsheet.

According to the essay test, it can be concluded that most of students understand the concept of discharging and charging capacitor after following the course. They were able to explain the important concept of differential equation in RC circuit. They wrote the correct answer that in charging capacitor, the potential difference of resistor decrease appropriately to Ohm's law and the potential difference of capacitor decrease appropriately to Q/C. They wrote that the charge (Qi) and current Ii has clausal effect, the charge in capacitor increase caused by the flowing charge to capacitor. More than 80% students gave correct answer that if the current is increase, the charge will increase too, this phenomena is appropriate to the theory that current as rate of change the charge. Just 50% students were able to give correct answer that in initial condition of charging capacitor, $Q = 0$ and $I=\varepsilon/R$.

3.2. Discussion

Based on the interview, we concluded that the most of the students very interested to follow the course. They said that they got the new knowledge to make a simulation using spreadsheet modeling. They said that using a spreadsheet in this course is very interested because they were familiar to the spreadsheet so they did not need to study new program to make a simulation . Our finding support to previous research that the use of spreadsheet make students active to make their own simulation is the best choice to teach computation [12]. In previous researches, especially in high school, the differential equation solved by Euler method use spreadsheet [10] and spreadsheet modeling [11,13]. In the research, the students just need to use the simulation, they did not need to make their own simulation. The result of this research completed the previous researches. Therefore, for the next research, we suggest investigating how to train students to make the computation based on the numerical method in a spreadsheet environment . It is also very important to investigate how students combine the simulation and laboratory practice to get the better understanding concept.

4. Conclusion

We concluded that spreadsheet modeling could be integrated with laboratory practice into undergraduate education physics curriculum. The students gave positive perceptions to this course and improving the student's ability in understanding the concept of feedback that is mathematically expressed in the differential equation The results of this research become a complement to the study on how to integrate in laboratory practice of learning physics use spreadsheet modeling for students who have not mastered differential equation.

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