Development of Smartphone e-Modul by Problem Solving Method for Biot-Savart Theory

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Abstract. Biot-Savart law is an equation that describes the magnetic field created by a current-carrying wire and allows you to calculate its strength at various points. Biot-Savart law is too difficult to be understood, especially about the mathematics concept. Based on the situation, developed an interactive media that’s an Electronic Module. This module based on the problem-solving method and can be accessed by smartphone. This research by using a development method, where is, an electronic module is created by Adobe Flash software. By the development of this module is expected that can improve the ability of mathematics concept analytical.

1. Introduction

Students of Electrical Engineering Education Study Program should be equipped with a mature understanding of the concepts of electromagnetic fields. It is intended that later if they become electro teachers, they can pass the understanding of the concept to the students [1]. The selection of the chapter on the law of Biot-Savart is intended to make the theory which is the basis for determining magnetic field strength can be understood first so that it will not lead to errors in conceptual understanding (misconception).

Some educational experts have undertaken research on misconceptions. For example, in 2014 Jeffry Handhika et al, developed a cognitive-charged medium of learning to reduce the alleged misconception of the elementary physics course [2]. Aydin and Balim in 2010 implemented a concept change strategy to eliminate misconceptions in students [3]. Previously, Baser explains the effect of using concept change steps on students' understanding of heat and heat. Some of these studies have reinforced the fact that misconceptions are a serious problem [4].

The terms of misconception are expressed differently by the researchers. According to David Hammer (1996) “misconceptions to refer only to the phenomenology of patterns in students’ responses that are inconsistent with expert understanding ”[5]. While Giuseppe and Fraser 2012 say that “The ideas and Explanations That vary significantly from accepted knowledge are typically called misconceptions or alternate conceptions[6].

Misconceptions can occur because of factors such as intuition [7], some things that are abstract and elusive, and the error of explanations from teachers, friends, or teaching resources. In order to reduce
misconceptions not only improve methods and learning models but also consider other factors such as teachers, teaching resources such as modules, books, and media.

From the observations that have been done previously obtained the fact that in the Electrical Engineering Education Study Program the field theory course is quite difficult to understand. After further observation, it was found that one of the elusive material is the Biot-Savart law. Both in terms of calculating the magnetic field mathematically, as well as the influence of each variable against the magnitude of the magnetic field magnitude.

Discussion about the law of Biot Savart is studied by students of Electrical Engineering Education who take the field theory course. The field theory course deals with the various theories relating to the electromagnetic field. As already known that the Ampere theorem and the Biot–Savart law is well-known tools used to calculate magnetic fields created by current distributions [8]. The determination of the magnetic field created by a rectilinear infinite wire is a classical problem that can be found in every electromagnetism book. The calculation is generally carried out by applying the Ampere theorem to a current circulation on a circle \( r \) of radius \( r \). Simple symmetry considerations indicate that the magnetic field is orthoradial with \( B = B(r) \mu_0 \), and the use of the Ampere law leads to the well-known result

\[
\mu_0 I = \oint \vec{B} \cdot d\vec{l} = 2\pi R |\vec{B}(r)| \Rightarrow \vec{B}(C) = \frac{\mu_0 I}{2\pi R} \tag{1}
\]

The equation model as seen in Equation (1) is an equation that is difficult to comprehend and solved for example by students in the electrical engineering education program. It is based on data in the form of final grades of students Electrical Engineering Education Study Program Semester 3 academic year 2015/2016 which shows the average value of only 67.85. Besides data, student difficulties can also be known from some opinions expressed by students at the time of the interview. Approximately 85% of students find it difficult to understand the equations in field theory, Biot Savart's law for example. Moreover, if you have to connect the equation with real electronics devices.

In the previous semester lectures, lecturers only use Slide Presentations, learning media using only whiteboards. Existing modules Only gives some similarities and concepts in a line Great about field theory. Some examples of problems and solutions are available In the module only refers to the completion of the mathematical case. Some references Mandatory owned by students also difficult to be understood, because according to the student There are some difficulties to connect the equation with the device Often used electronics. And also, the choice of words used is also more complicated. It is based on interviews that have been done with some Students who have taken courses in Medan Theory.

Based on these conditions, an interactive learning media is required. Learning media more communicative and can facilitate students in learning about the theory of electromagnetic fields, especially about the law of Biot-Savart. One of the media that can be used is media e-Module based smartphone. Where the e-Module media can be accessed via smartphone, so it can be used anywhere. This media uses problem-solving method because the interactive model of e-Module is solving some mathematical calculation problem related to Biot-Savart law

2. Biot-Savart Law

The currents which arise due to the motion of charges are the source of magnetic fields. When the charges move in a wire at a certain velocity can produce a current \( I \), the magnetic field at any point \( P \) due to the current can be calculated by adding a small part of magnetic field \( dB \), from small segments of the wire \( ds \), (Figure 1.1)

These segments can be assumed as a vector quantity. It has a magnitude of the length of the segment and pointing in the direction of the current flow in the wire. The source of current is very small and be written as \( I ds \) [9].

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**Figure 1.1**

A diagram illustrating the Biot-Savart law.
Figure 1. Magnetic field $d\mathbf{B}$ at point $P$ because the effect of the current on the wire

Let $r$ denote as the distance from the current source (in this case is a wire) to the field point $P$, and $\hat{r}$ the corresponding unit vector. The Biot-Savart law gives an expression for calculating the magnetic field contribution, $d\mathbf{B}$, from the current source, $Ids$, and the equation of Biot-Savart Law is

$$d\mathbf{B} = \frac{\mu_0 Ids \times \hat{r}}{4\pi r^2}$$

Where $\mu_0$ is a constant called the permeability of free space, with the value $4\pi \times 10^{-7} T\cdot m/A$.

Biot-Savart law is used to determine the magnetic field strength either on a straight wire, circular, solenoids or toroid. By an integral part, we can find the magnetic field strength either on a straight wire, circular, solenoids or toroid [10]. In addition to previous research, the Biot-Savart law can also be used as a theoretical basis for determining the electromagnetic energy of the solenoid in the form of special relativity [11].

3. Problem-Solving Method for Mathematics Learning

Problem-solving in mathematics is divided into three interpretations, namely problem solving as a goal, problem-solving as a process, and problem-solving as a basic skill [12]. In mathematics, first, problem-solving is used as one of the learning objectives. In this case, problem solving does not depend on specific problems or problems, procedures, or methods, and also the content of mathematics. Second is problem-solving as a dynamic process. In this aspect, problem-solving can be interpreted as a process of applying all knowledge possessed to new and unusual situations. In this interpretation, what needs to be considered are methods, procedures, and strategies used by students in solving a problem. Last is problem-solving as a basic skill. In this interpretation, more emphasize problem-solving as the basic skill of counting.

4. Method

This research method is research and development. Subjects in this study were students at the PGRI Madiun University who take a course in Electromagnetic Field (17 students). Data were collected through the e-Module media test. Media that has been created using Adobe Flash has tested eligibility and validated first by some expert lecturers related to the field of science of Electromagnetic Field and lecturer of media learning experts. Media that has been declared feasible, tested to students with the problem-solving method. Where students are given initial knowledge about the concept of Biot-Savart law theory. The following concepts have been described in a mathematical equation model. In turn related to the method of problem-solving, students are given feedback in the form of influence given by each variable that affects the magnetic field value based on Biot-Savart law equation. By using the media, students must be able to present the influence of each of these variables. After that stage is reached, the student is given a conceptual case concerning the Biot-Savart law that must be completed.
using e-Module media simulation. But previously the students are guided to be able to declare language problem in the mathematical language.

5. Result and Discussion
This result is obtained from the pre test and post test conducted on 15 respondents (students). The first problem is understanding the concept of the variables that affect the magnetic field strength. And the second about the completion of mathematical calculations to determine the strength of the magnetic field. The result showed by Table 1.

| Test | Aspect of Research | Result | N-Gain |
|------|-------------------|--------|--------|
| 1. Magnetic Field Strength of Straight Wire $B = \frac{\mu_0 I}{2\pi r}$ | Before: 13.3% | After: 66.7% | 0.4 |
| | The change of variable $I$ (current) influences the value of the magnetic field strength ($B$), where if the value of the current flowing large (the amount of electric charge ($q$) flowing a lot) then the field strength increases, and vice versa. However, if the distance ($r$) between the electrical current wire with a point around the wire farther, then the magnetic field strength is reduced, and vice versa. | | |
| | Can calculate the value of magnetic field strength | 13.3% | 46.7% | 0.3 |
| 2. Magnetic Field Strength of Circular Wire $B = \frac{\mu_0 I}{2\pi r}$ | Before: 20.0% | After: 73.3% | 0.4 |
| | Changes in variables I and a give effect such as the application of Biot-Savart Law on straight wire, | | |
| | The explanation of the difference between the first and second equations can be explained mathematically. | 20.0% | 73.3% | 0.4 |
| | Can calculate the value of magnetic field strength and the influence of variable change, but without explanation about the differences with the first equation (for straight wire) | 20.0% | 53.3% | 0.4 |
| 3. Magnetic Field Strength of the Axis of Solenoid $B = \frac{\mu_0 I}{L} N$ | Before: 26.7% | After: 80.0% | 0.5 |
| | The change in the value of variables I and N is proportional to the magnetic field strength value ($B$), whereas L is inversely proportional. | | |
| | It is an equation for determining the strength of the magnetic field on the solenoid axis, which is twice as large as the solenoid end | 26.7% | 80.0% | 0.5 |
| | Can calculate the value of magnetic field strength and the influence of variable change, but without explanation about the differences with the equation of magnetic field strength as the axis of the solenoid. | 26.7% | 66.7% | 0.4 |
| 4. Magnetic Field Strength of the End of Solenoid $B = \frac{\mu_0 I}{2L} N$ | Before: 26.7% | After: 80.0% | 0.5 |
| | The change in the value of variables I and N is proportional to the magnetic field strength value ($B$), whereas L is inversely proportional. | | |
• It is an equation for determining the strength of the magnetic field on the axis of the solenoid, which the value is half of the value in the solenoid axis. Can calculate the value of magnetic field strength and the influence of variable change, but without explanation about the differences with the equation of magnetic field strength as the axis of the solenoid.

\[ B = \frac{\mu_0 I}{\pi a} N \]

5.

• The change in the value of variables I and N is proportional to the magnetic field strength value (B), whereas a is inversely proportional. The value of a is the average radius of the toroid obtained by the equation \((a_1 + a_2) / 2\). Can calculate the value of magnetic field strength

|        | 40,0 % | 80,0 % | 0,4 |
|--------|--------|--------|-----|
| Magnetic Field Strength of Toroid \(B = \frac{\mu_0 I}{\pi a} N\) |        |        |     |
|        | 20,0 % | 86,0 % | 0,6 |
|        | 46,7 % | 80,0 % | 0,5 |

Graph 1. Graph of percentage of pre test and post-test values for the first question

The results in Table 1 are outlined in Graph 1 and Graph 2. Graph 1 shows the student's pre-test and post-test results from the first test (magnetic field strength on a straight wire) to five (magnetic field strength in toroid) for the first type of question. For the first pre-test to post-test to four percentage of students who are able to solve the problem has increased, but when the pretest to five percentage decreased. After analyzing, it is because the type of problem on the fifth pre-test (magnetic field strength in toroid) students must first understand the effect of the radius of toroidal to the area, then connect it with magnetic field strength.

As for the posttest score, the graph shows that the percentage of the number of students who understand the concept of the Biot-Savart law increases with the medium Gain category (0.5 to 0.6). The Gain score is calculated following the equation [13]. After analyzing the students' value, it is concluded that the students of Electrical Engineering Education Study Program need more practice until they can understand the concept of the influence of certain variables on magnetic field strength.

Graph 2 shows an increase in the pretest and posttest results of students for the second type of question (mathematical calculation). In the pretest for the second question, it increases from the first to the fourth but decreases in the fifth question. This is because on the fifth question (field strength in toroid) students must first determine the area of the toroid, then proceed to determine the strength of
the field. As for the post, the test has increased, starting from the first test until the fifth test, with the category of medium gain (0.5 to 0.6). Based on the results of research that has been developed, it can be seen that with the e-Module Smartphone module students Electrical Engineering Education Studies University PGRI Madiun can more easily accept the material about the concept of mathematical calculations on Electromagnetic Field Theory focus material Biot-Savart Law.

Graph 2. Graph of percentage of pre test and post-test values for the second question

Based on the all of the result, by using smartphone e-Modul understanding of the five derived equations of the Biot-Savart Law equation increases, with the medium gain category.

Figure 2. Sample media display on smartphone

Improved understanding focuses on the understanding of the influence of each variable of the principal quantities on magnetic field strength and mathematical arithmetic to determine the strength of the magnetic field. This is due to the e-Module media for the simulation part set for both fields. To calculate the magnetic field strength using e-Module, students only enter the value of the required variables, then tested, then the program will automatically calculate the strength of the magnetic field.
6. Conclusion

The mathematical concept of the law of Biot-Savart can be understood more easily using e-module based smartphone media. The application of this media can improve students' understanding of mathematical concepts, as evidenced by the increase in the percentage of the number of students who can solve problems related to mathematical concepts of Biot-Savart Law. Increasing the percentage with the category of medium gain (0.5 to 0.6). For the future can be developed again similar media but supported by its real equipment. So in addition to understanding, students are also able to apply the concept directly.

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