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PAPER**Analysis of graphical representation among freshmen in undergraduate physics laboratory**

3

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² Analysis of graphical representation among freshmen in undergraduate physics laboratory

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Abstract. Physics concept understanding is the importance of the physics laboratory among freshmen in the undergraduate program. These include the ability to interpret the meaning of the graph to make an appropriate conclusion. This particular study analyses the graphical representation among freshmen in an undergraduate physics laboratory. This study uses empirical study with quantitative approach. The graphical representation covers 3 physics topics: velocity of sound, simple pendulum and spring system. The result of this study shows most of the freshmen (90% of the sample) make a graph based on the data from physics laboratory. It means the transferring process of raw data which illustrated in the table to physics graph can be categorised. Most of the Freshmen use the proportional principle of the variable in graph analysis. However, Freshmen can't make the graph in an appropriate variable to gain more information and can't analyse the graph to obtain the useful information from the slope.

1. Introduction

Transferring process of raw data is an important part of physics laboratory to make analysis process easier. It can transform in table or graph to make an appropriate conclusion. The proportional principle easy to describe when the raw data transferred into the graph [1]. It shows clearly the relation between variables [2]. In the experiment, there are several types of variables. The independent, dependent and control variables. The independent variable is the one condition that changes in an experiment. The dependent variable is the variable that measures or observe. A controlled variable or constant variable is a variable that does not change during an experiment [3]. The tendency of one variable to other not necessarily show a straight-line trend [4]. A graph can show the specific constant according to some physical law and aberrant data in sequence. It shows up in the graph clearly. A mistake from plotting graph in variable or experiment can detect from graphical representation [5].

The graph should show enough data because a lot of data make an appropriate decision to take better conclusion. Clearly, it needs more than two points for data plotting in the graph, more data should be taken to confirm that the data are real [5] such as the region around the velocity of sound. If there are too few data, the velocity of sound will fail to see in the long range. It never knows the velocity in any range as long as the resonance tube. In a spring system, a lot of data will show the elastic limit of the specific spring. The elastic limit of spring depends on the material of spring and it is the condition when spring permanently stretched so that the material doesn't return to its original length when the force is removed. In a simple pendulum, a lot of range of angle will show that the



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simple pendulum equation unvalued. That equation doesn't express for any angles, but in a few angles (less than about 10°) [6].

If the data is uncorrelated and no relationship between variables, further analysis isn't necessary. But in quantitative data such as the velocity of sound, simple pendulum and spring system topics need to establish the mathematical relationship between the variables. The graph should transform the linear graph to analyse it easier [7]. In the linear graph, the gradient of the graph can use to determine the specific constant according to some physical law [8]. In the velocity of sound, constant gradient use to determine the velocity of sound. In simple pendulum topic, constant gradient use to determine the gravitational acceleration. In the spring system, gradient used to determine the spring constant [6,9].

The representation such as diagram and graph play a critical role in the effectiveness of the interactive engagement between students in these physics learning an environment [10]. The graph is very important because there is a proportional principle. This proportional principle gives the dependent and independent variable for the experiment describes due to the aim [11]. The graph depicting a physical proportional which cannot easily be recognized in the table of the same data [12]. There is a tendency among freshmen and graph proportional view and a tendency among incorrect existing knowledge and graphing problem to gain more information from the graph [13].

Physics laboratory for freshmen is the activities in a basic physics course. It consists of mechanics and thermodynamics topics [14]. After getting the related information in class, freshmen apply the physics' concept in the laboratory. That concept isn't only about the physics' principle but also how that principle gets rationally [15]. Physics concept understanding is the importance of the physics laboratory, especially in mechanics and thermodynamics concept. So, the appropriate analysis of data takes to the correct conclusion. For that reason, a graphical representation is required. Based on the importance of graph to make an appropriate conclusion for freshmen, so it is necessary to analyse the graphical representation among freshmen in undergraduate programs.

2. Method

2.1. Context and participants

This particular research uses the experiment data of 20 freshmen's laboratory report in basic physics class at the State University of Surabaya (Universitas Negeri Surabaya), Indonesia. Freshmen are typically first-year students the undergraduate program, all taking the basic physics course as part of physics education and the physics study program. The course is taken in the first semester of 2017. Freshmen have 2,5 hours per week in the laboratory, with 2,5 hours lecture per week in class, and meet for a pre-laboratory session before taking laboratory activities. The pre-laboratory sessions are generally traditional, with freshmen answering questions related to the topic with laboratory assistant.

2.2. Data and analysis

The sources of data for these studies are freshmen's experimental report in the velocity of sound, simple pendulum and spring system topics. It chooses 20 randomly from a group and from all classes. It analyses in the indicator adapted from Christopher Deacon [5]. More particularly, the indicator items are shown in the Table. 1. In this research, the indicators are slightly modified to questions form. The result of this analysis is recapitulated and the graphs of the freshmen are studied in detail.

Table 1. Indicator of graphical representation.

	Yes	No
Do freshmen make a graph?		
Do freshmen use appropriate variable in its axis?		
Do freshmen use proportional principle?		
Do freshmen use gradient analysis?		
Do freshmen use aberrant data analysis?		

3. Results

This section starts by presenting the detailed result of the graphical representation of freshmen experimental report in the velocity of sound, simple pendulum and spring system topics. The second part is the analysis of the whole data. These studies are based on modification in the original indicator from Christopher Deacon [5].

3.1. Initial study: Graphical representation findings

In the first study, the graph took from the experimental report in the data and analysis chapter and focus on information from graph analysis.

3.1.1. Velocity of sound. This topic aims to know the proportionality between the frequency of sound and length on first harmonic. Moreover, this topic aims to determine the velocity of sound in the air. The appropriate graph for this topic shown in figure 1. Period (1/frequency) is proportional to the length on the first harmonic and the velocity of sound (v) obtains with an equation 1 with m is a gradient of the slope in figure 1.

$$v = 4m \quad (1)$$

Based on the graph shown in figure 1, the speed of sound in the air can be determined as follows:

$$v = 4m = 4 \times 84,046 = 336.18 \text{ m/s}$$

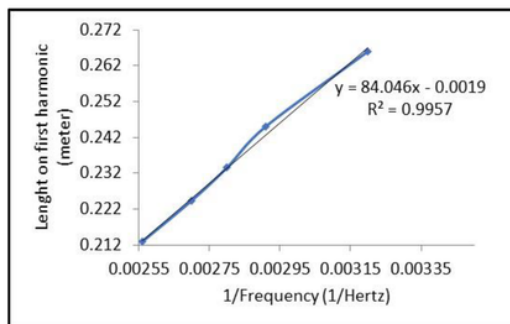


Figure 1. Graph plotted to obtain the velocity of sound.

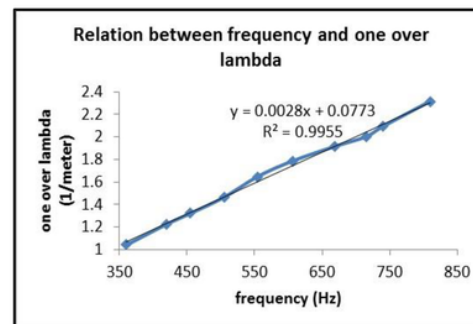


Figure 2. Freshman's graph interpretation of the experiment report.

In this topic, the independent variable is plotted in x-axis as one over frequency and dependent variable plotted in y-axis as a length of first harmonic. Both of x-axis and y-axis didn't contain control variable. From the graph, an increase of the period causes the increase of length in the first harmonic (period and length of first harmonic have linear proportionality) or an increase of the frequency cause decrease of the length at the first harmonic (frequency and length in first harmonic have inverse proportionality). From this variable in an axis, the slope of the graph is used to determining the velocity of sound. Besides this model, there is another graph to determine the velocity of sound using a length of the second harmonic in the y-axis. It will show the same value of the velocity of sound.

In freshman's graph shown in Figure 2 titled as 'relation between frequency and one over wavelength', frequency directly proportional to one over the length of harmonic. This graph shows the mistake. It doesn't explain the number of harmonic in that graph. This topic uses closed-end air columns and there are two harmonics, first and second harmonic. This graph can't use to determine the speed of sound and freshmen didn't analyse that. Freshmen just analyse proportionality of this graph. Most of the freshmen use the proportionality by writing the linear proportionality or the increase of

frequency causes the increase of variable in y-axis such as wavelength and length of first or second harmonic.

At figure 2 shown, freshmen use one over a wavelength in y-axis used to make the slope increase. This is the miss-understanding among freshmen that slope didn't use to determine any constant due to determine the velocity of sound. This miss-understanding also found at no one freshmen use a gradient to determine the velocity of sound. The gradient just is shown in the graph without any analysis.

3.1.2. Simple pendulum. This topic aims to know the proportionality between the length of string and period. Moreover, this topic aims to determine the gravity acceleration of earth. An appropriate graph for this topic shown in figure 3. From the graph in figure 3, the length of the string is proportional to the square of the period and gravity acceleration of earth (g) obtains with the equation 2 with m is a gradient of the slope in figure 3 and l is the length of the string.

$$g = \frac{4\pi^2 l}{m} \quad (2)$$

Based on the graph shown in figure 3, the gravity acceleration of earth (g) can be determined as follows:

$$g = \frac{4\pi^2}{m} = \frac{4 \times 3,14^2}{4,0152} = 9,84 \text{ m/s}^2$$

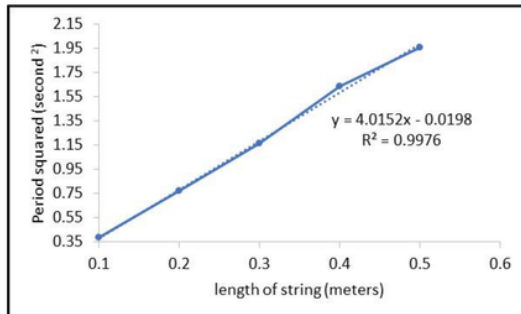


Figure 3. Graph plotted to obtain gravity acceleration of earth.

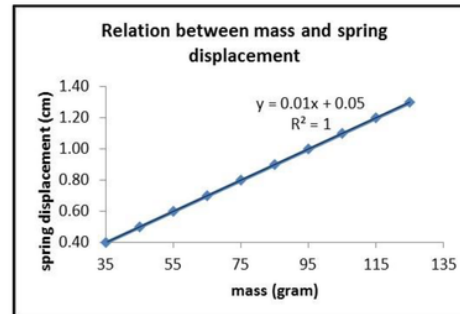


Figure 4. Freshman's graph interpretation of the experiment report.

In this topic, the independent variable is plotted in x-axis as the length of string and dependent variable plotted in y-axis as the square of the period. Both of x-axis and y-axis didn't contain control variable. From the graph, raising length of string cause the increase of the square of the period (the length of string and square of the period have linear proportionality). From this variable in the axis, the slope of the graph is used to determining the gravity acceleration of earth.

In freshman's graph shown in figure 4 titled as 'relation between string length and period', the length of the string directly proportional to the period. This topic uses small angle (less than 10°) in the pendulum system. This graph can't use to determine the gravity acceleration of earth and freshmen didn't analyse that. Freshmen just analyse proportionality of this graph. Most of the freshmen use the proportionality and write linear proportionality or the increase of string length causes the increase of period.

3.1.3. Spring system. This topic aims to know the proportionality between mass and spring displacement. Moreover, this topic aims to determine spring constant. The appropriate graph for this topic shown figure 5. From the graph in figure 5, the mass is proportional to spring displacement and

spring constant (k) obtains with the equation 3 with m is a gradient of the slope in figure 5 and g is gravity acceleration of earth ($g = 9,8 \text{ m/s}^2$).

$$k = \frac{g}{m} \quad (3)$$

Based on the graph shown in figure 5, the spring constant (k) can be determined as follows:

$$k = \frac{g}{m} = \frac{9,8}{0,1933} = 50,7$$

In this topic, the independent variable is plotted in x-axis as mass and dependent variable plotted in y-axis as spring displacement. Both of x-axis and y-axis didn't contain control variable. From the graph, an increase of mass causes the increase of spring displacement (mass and spring displacement have linear proportionality). From this variable in the axis, the slope of the graph is used to determining the spring constant.

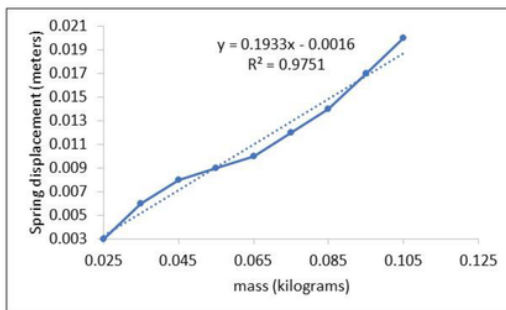


Figure 5. Graph plotted to obtain spring constant.

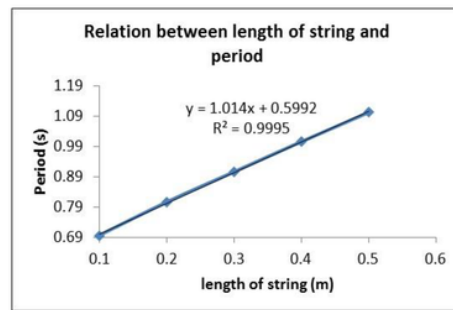


Figure 6. Freshman's graph interpretation of the experiment report.

In the freshman's graph shown in figure 6 titled as 'relation between mass and spring displacement', mass directly proportional to spring displacement. The graph in figure 6 shows that the variable in x-axis and y-axis are appropriate, but freshmen didn't use to determine the spring constant. Freshmen just analyse proportionality of this graph. Most of the freshmen use the proportionality and write linear proportionality or the increase of mass causes the increase of spring displacement.

3.2. Analysis

Graph representation on freshmen's experiment report is compiled to table 2 below. This table will show the graphical representation among freshmen.

Table 2. Graphical representation among freshmen

	Yes		No	
Do freshmen make a graph?	18	90%	2	10%
Do freshmen use appropriate variable in its axis?	10	50%	10	50%
Do freshmen use proportional principle?	18	90%	2	10%
Do freshmen use gradient analysis?	0	0%	20	100%
Do freshmen use aberrant data analysis?	0	0%	20	100%

Based on the table above, most of the freshmen (90% of the sample) can make a graph derived from the data of the physics laboratory. It means the transferring process of raw data which illustrated in the table physics graph can be categorised. Freshmen who made graph didn't make a mistake in transferring the raw data into a graph. Most of the freshmen also use proportional principle on their graph. It means, all of the freshmen who make graph use proportional principle, although half of sample use an inappropriate variable in x-axis and y-axis. They have understood that graph is used to show proportionality between variables easily.

In graph axis, half of the freshmen use an appropriate variable like describe at the previous part and half of the freshmen make inappropriate variable. All of the freshmen who make inappropriate variable use an independent variable in the x-axis and dependent variable in y-axis without any consideration to gain more information from the graph.

In gradient using, freshmen didn't analyse the gradient from the graph. Actually, the gradient important to determine specific value in every topic. From this procedure, a specific value shows the universal value in every independent value. Freshmen also didn't analyse the aberrant data from the graph. Aberrant data in a sequence of measurements will usually show up in the graph more readily than in a table of data.

Freshmen use *Microsoft Excel*™ to make their graph. McKenzie and Padilla state that graphs are an important tool in enabling students to predict relationships between variables and to substantiate the nature of these relationships. They suggest a relationship between the student's graphing skills and their ability to understand scientific relationships [16]. At this research, the relation between the computer-based graph and the ability to understand scientific relationships aren't noticed. This also notices the reason for freshmen didn't the ability to use an appropriate variable, gradient analysis and aberrant analysis.

A graph is a tool for data analysis. As the other tools, the effectiveness of the tools will depend on the user's proficiency. A competence freshman will be able to make and interpret the graph. Physics concern for natural phenomena and mathematics describes these phenomena in the term of the equation and predict the behaviour of the physical system as conditions change. A well-drawn graph provides the combination between physics and mathematics.

A good data is needed to make a good graph. A good understanding in order to get more information from the graph. Based on five fundamental steps to produce a good graph [5], before plotting the data, the aim of the experiment should be clearly set and can be answered. After that, plotting the data to the easy visualize the unit, linear function graph and choose useful variable in axis due to gain more information (use any software to produce graph easily). Then use the slope and interpret it to obtain physical specific's constant as well as describe the relation with experiment. For physics laboratory activity, the good graph producing must be explained to the freshmen due to experiment activity. This explanation must be well-understanding for freshmen and show the whole process from transferring process of the raw data to the graph analysis.

4. Conclusion

Most of the freshmen (90% of the sample) make a graph based on the data from physics laboratory and use the proportional principle of the variable in graph analysis. It means the transferring process of raw data which illustrated in the table to physics graph can be categorised and freshmen understand the main function of the graph as tools. However, some freshmen (50% of the sample) can't make the graph in an appropriate variable to gain more information and can't analyse the graph to obtain useful information from the slope and no one freshmen use the gradient and aberrant data analysis. A good graph produces from five fundamental mentioned and need the whole graphical process explanation.

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PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8