COMPUTER-BASED EXPERIMENT OF FREE FALL MOVEMENT TO IMPROVE THE GRAPHICAL LITERACY

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ABSTRACT

The purpose of this study is to develop computer-based experiment of free fall movement to improve the graphical literacy of the Physics Education students. This study employed quasi-experimental design, particularly the pre-test and post-test control group design. The sample was 58 students of the first semester of Physics Education study program. They were divided into two groups, namely 38 students constituted an experimental group and 20 students constituted the control group. Both groups joined learning activities at laboratory and classrooms with the same topic which is the free fall movement. Computer-based learning models were used to design learning activities for the experimental group, while the control group used a traditional learning model with manual experiment with stopwatch and never use experiment tool of free fall movement. It was indicated in this study that the use of such learning model improved the graphical literacy capability better than the traditional learning, which covered ability to identify experimental variables, using the experimental tools, making a graph, formulating mathematical equation, making predictions on the basis of the graph.

INTRODUCTION

On the subject of Basic Physics 1, there is a topic about the movement kinematics of free fall movement. The measurement model of the free fall experiment has used traditional method since years, namely by using a stopwatch to measure the time of an object to fall from certain height. There is now a research which has successfully developed a set of microcontroller-based free fall movement experiment with a PC display. The result of the tool development has created the tool which can measure the acceleration of the earth gravity accurately, which is 98.3% (Dasriyani et al. 2014). The review of the research suggested that the tool only showed the graph of g value,

without any feature to show the graph equipped with the other parameters such as the influence of mass, object shape, and height as an effort to improve the students understanding towards the concept of free fall movement (Dasriyani et al. 2014). The recent study of computer-based learning of free fall motion had been shown that coupling real life phenomenon with computer modeling in free fall motion can help the students' understanding the concept (Wee et al. 2015). Therefore, further, development is needed to produce a computer-based free fall movement tool to improve the graphical literacy.

In a pre-test of movement kinematics, we found that most of the students had not understood the concept of free fall movement well (Bambang, 2012). For instance, (1) when an object falls from a certain height, the mass and sha-

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pe of the object affect the falling time; (2) when two objects with the same mass and shape fall from a different height, it gives a different value of the earth gravity acceleration. Learning these empirical facts, we are interested in developing a computer-based learning strategy of free fall movement to delve the graphical literacy capability. In order to ease the explanation of free fall movement concept for the students, we need to teach the procedure and process of making the graph first.

In order to support the activities in kinematics learning which develop the graphical literacy, several learning models should be combined (Bambang, et al. 2015a). It is because the learning process of free fall movement starts from the problem that the students get from the lecture and then it is continued by solving the problem through activities in the laboratory. When the students create a graph, they need a kind of software to present data in a graphic and to interpret it. Thus, in this research, we used multiple model instructions to teach the computer-based free fall movement to delve their graphical literacy.

Graphical literacy is a construction which describes the ability to understand the information presented in the form of a graph (Okan, et al. 2012). The Programme for International Student Assesment (PISA) 2013 set the graphical literacy capability in the situation and context within PISA framework (PISA, 2013). This phenomenon is important since PISA has been a parameter of education success in a country. Thus, students of primary education should have been taught about the graphical literacy and the future teachers. Therefore, they should also have a provision about graphical literacy. Through the graphical literacy capability, the students are capable of interpreting the graph. The students need to understand how to analyze data and how to draw a conclusion from a graph.

Some lecturers have used the graph to explain concepts in their class, but they have not explicitly taught the way of this visual communication (Colemen, et al. 2011) The low understanding towards the graphical literacy of the students will affect their understanding towards kinematics concepts. They are teacher candidates who have to master the graph interpretation and have to explain to their future students about it in both oral or written. Based on the early limited finding of graphical literacy capability of students in bachelor degree and master degree of Physics Education study program in Bandung, it shows that: (1) 46% of students of bachelor degree and master degree in Physics education still have difficulties

in making graph, (2) the students' capability in interpreting graph is very low which is only 13% (Bambang, 2012; Sharma, 2005 & Sutopo, 2013).

Various efforts have been conducted by the previous researches to identify and to overcome the students' difficulties related to the graphical literacy. The research found that the ability to interpret graph is influenced by the characteristics of the graph, for instance, the form, type, content, and the initial knowledge about the graph (Glazer, 2011). Similar researches suggest that understanding graph is influenced by their data interpretation context (Roth and Bowen, 2003). For instance, the students' understanding towards the content affects the ability to analyze and to describe the data. The next research found that the students were difficult to read, to interpret, and to understand the information presented in a graph (Didem, et al. 2012; Sezen et al. 2012; Uzun et al. 2014).

Based on the review of these results, we have not found any research concerned to improve graphical literacy through computer-based learning strategy of free fall movement. Thus, we dedicate this research to do so. The research problems are: how is the learning strategy in free fall movement material to delve the student's graphical literacy and equipped by supporting facilities? while the research purpose is to produce computer-based learning strategy of free fall movement to delve the graphical literacy capability of the students.

METHODS

This research used quasi-experimental design which was the pre-test and post-test control group design, as shown in Table 1. The sample of this research was 58 students of the first semester of Physics Education study program. It consisted of two groups, namely 38 students constituted the experiment group and 20 students constituted the control group. Both groups joined learning activities at laboratory and classrooms with the same material which was the free fall movement. The experiment group used a computer-based experiment tool of free fall movement; while the control group used a manual one which was the stopwatch as an experiment tool of free fall movement.

The instruments used test and non test. The test was used to measure the students' concept understanding before and after the learning process, while the non test instrument was an observation sheet to measure the experiment activity of free fall movement.

Table 1. Pre test and post test control group research design

Groups	Pre test	Treatment	Posttest
Experiment	O1	X	O2
Control	O2	-	O2

RESULTS AND DISCUSSION

The learning strategy developed in this research is multiple models instruction. The learning strategy resulted here is the elaboration of problem-based learning model, laboratory inquiry, and computer-based learning as shown in Figure 1.
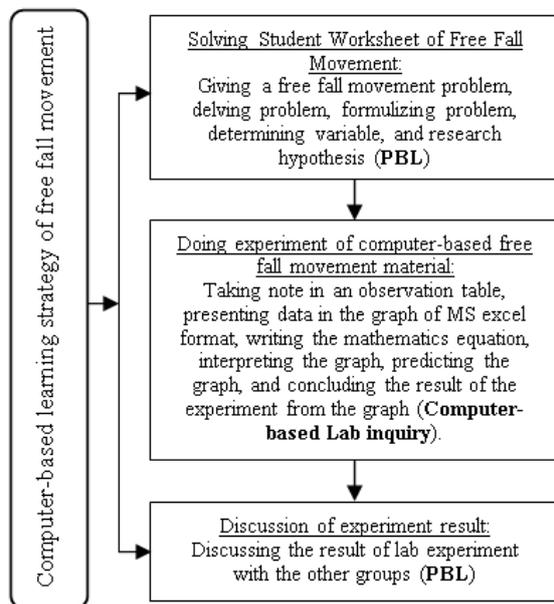

Figure 1. Computer-based learning strategy of free fall movement

The learning procedures of the computer-based learning strategy of free fall movement are as follow:

Students are given a worksheet. They have to read and learn the problems given in the worksheet, to formulate the problem, to determine the research variable, and to construct a hypothesis.

Students do a laboratory experiment to solve the free fall movement. The computer-based learning strategy is as follows: students construct the experiment device of computer-based free fall movement and setting the device as shown in Figure 2.

Figure 2. Setting the computer-based device of free fall movement.

Inputting the data (mass, height) and setting the USB port.
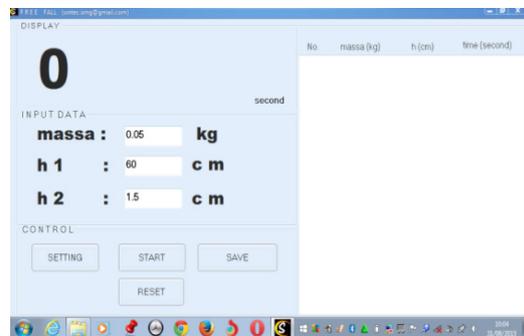
Figure 3. Display interface of the computer-based experiment of free fall movement

Dropping objects with a variation of mass, shape, and height in minimum 10 times.

This step was done in order to get the relationship between mass, shape, and height with the gravity acceleration. The students use any things they have in their pencil case as a dropping object. The data were presented in Figure 4.
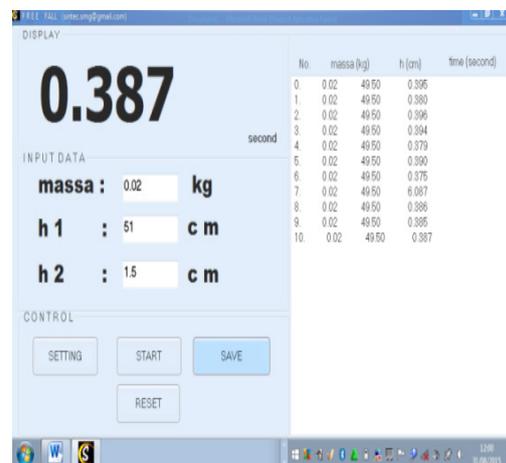
Figure 4. Display of the experiment result of the computer-based free fall movement

Saving the experiment data by clicking Save, and then checking the data display in the form of MS Excel and graph, and then presenting the data in the form of a graph.
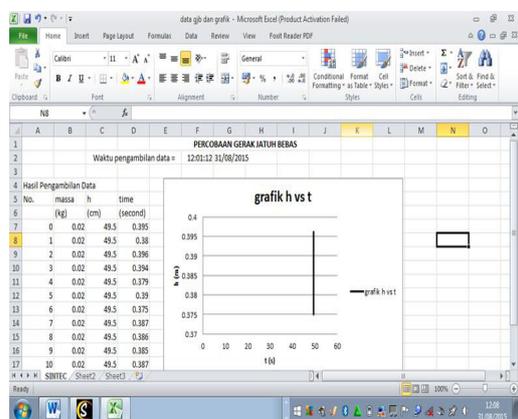
**Figure 5**. Data display of the experiment in MS Excel display

Writing a report, presenting the observation data in Ms. Excel graph, writing the mathematics equation, interpreting the graph, predicting the graph, and concluding the experiment result based on the graph display.

Designing the device of free fall movement. Below is the illustration of experiment tool design of free fall movement which is computer based and equipped with a sensor.
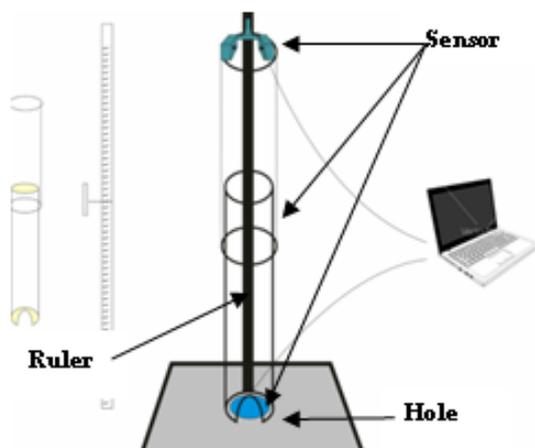

Figure 6. The sample of a design result of the student's experiment of computer-based free fall movement.

The activities measured in this learning process are: (1) the students' ability to formulate research questions based on the fact directly observed from the free fall movement device, (2) identifying research variable, (3) operating the device, (4) reading the measurement result, (5) making graph variation, (6) formulating the mathematics equation, (7) interpreting the graph, (8) predicting the graph, (9) concluding the result of experiment, and (10) designing the innovative device of free fall movement. The working assessment rubrics to measure the learning activities of the computer-based experiment of free fall movement is as shown in Table 2.

Table 2. Rubrics of the computer-based experiment of free fall movement to improve the students' graphycal literacy.

Activities and Description Score
Formulating research questions based on the fact directly observed from the free fall movement device. Description of the score: 1. Unable to formulate research questions based on the fact directly observed from the free fall movement device. 2. Able to formulate research questions but the questions are not focused on the fact directly observed from the free fall movement device. 3. Able to formulate research questions based on the fact directly observed from the free fall movement device.
Identifying research variable (dependent variable, independent variable, and control variable), and formulizing hypothesis. Description of the score: 1. Unable to identify research variable (dependent variable, independent variable, and control variable), and unable to formulate hypothesis correctly. 2. Able to identify research variable (dependent variable, independent variable, and control variable), but unable to formulate hypothesis correctly. 3. Able to identify research variable (dependent variable, independent variable, and control variable), and able to formulate hypothesis correctly.

Activities and Description Score

Operating the deviceto test the hypothesis.
Description score:
1. <u>Unable</u> to operate the deviceto test the hypothesiswell and correctly, so they always need help from the lecturer or the other groups.
2. <u>Able</u> to operate the deviceto test the hypothesiswell and correctly, <u>though</u> they sometimes need help from the lecturer or the other groups.
3. <u>Able</u> to operate the deviceto test the hypothesis well and correctly without help from the lecturer or the other groups.

The ability to collect data from the measurement.
Description score:
1. <u>Unable</u> to collect data completely based on the purpose of the measurement.
2. <u>Only able</u> to collect <u>some</u> of the data based on the purpose of the measurement.
3. <u>Able</u> to collect data completely based on the purpose of the measurement.

The ability to make a graph.
Description score:
1. <u>Unable</u> to create a graph, *unable* to write the scale of the axis, label, and unit correctly.
2. <u>Able</u> to create a graph <u>not</u> in the smooth way <u>though</u> the axis scale, label, and unit have been written correctly.
3. <u>Able</u> to create a graph in a smooth way, the axis scale, label, and unit have also been written correctly.

The ability to formulate the mathematics equation from a graph.
Description score:
1. <u>Unable</u> to formulate the mathematics equation based on the graph created.
2. <u>Able</u> to formulate the mathematics equation based on the graph created <u>though it is not correct</u>.
3. <u>Able</u> to formulate the mathematics equation based on the graph created.

The ability to interpret the graph.
Description score:
1. <u>Unable</u> and <u>there is no effort</u> shown to interpret the graph <u>correctly</u>.
2. <u>There is an effort</u> to interpret the graph though the interpretation <u>is not correct</u>.
3. <u>Able</u> to interpret the graph correctly.

Activities and Description Score

The ability to predict the graph.
Description score:
1. <u>Unable</u> and <u>there is no effort</u> shown to predict the graph <u>correctly</u>.
2. <u>There is an effort</u> to predict the graph though the prediction <u>is not correct</u>.
3. <u>Able</u> to predict the graph correctly.

The ability to conclude the experiment result according to the graph.
Description score:
1. <u>Unable</u> and <u>there is no effort</u> shown to conclude the experiment result based on the experiment purpose and the graph created.
2. <u>There is an effort</u> to conclude the experiment result, <u>though it is not suitable</u> for the experiment purpose and the graph created.
3. <u>Able</u> to conclude the experiment result based on the experiment purpose and the graph created.

The ability to design the device of free fall movement.
Description score:
1. <u>Unable</u> to design the device of free fall movement.
2. <u>There is an effort</u> to design the device of free fall movement, though it is a lack of innovation.
3. <u>Able</u> to design the device of free fall movement with high innovation and creativity.

Based on the collection score collected for the pre and post test from experiment and control group results are shown in Table 3.

Table 3. The students' graphical literacy

	Pre-test		Post-test		N-gain	
	Exp	Ctrl	Exp	Ctrl	Exp	Ctrl
N	38	20	38	20	-	-
Mean	66.7	58.4	90.3	84.1	0.7	0.6
SD	15.6	20.1	9.9	8.7	-	-
Std. Error Mean	2.5	4.5	1.60	1.9	-	-

Based on Table 3, it could be explained that the initial ability of the graphical literacy for the experiment group was better (M = 66.68; Std. Error M = 2.52) than the control group (M = 58.40; Std. Error M = 4.48). After the learning of free fall movement using computer conducted, there was a significant improvement of the graphical literacy of the experiment group (M = 90.29; Std. Error M = 1.60) and also for the control group

(M = 84.05; Std. Error M = 1.92). It showed that the learning strategy in both groups could foster the students' graphical literacy. However, if we compare between the strategies, we could see that the computer-based learning strategy could delve the graphical literacy ability more than the traditional strategy. It could be seen from the calculation of normalized gain; the experiment group was better (N-gain = 0.71) than the control group (N-gain = 0.62). The learning which combines the problem based learning, lab inquiry, and assisted by computer have been able to help students to understand the concept of free fall movement well. This finding is at an agreement with research by Ismail et al. (2016) that by exploring multimedia can help students in science learning by giving access to information, measuring, and analysis.

From the analysis results, the difference in impact between the implementation of computer-based learning strategy of free fall movement and traditional learning from the statistical analysis of independent sample t test is shown in Table 4. The gain, t (56) = 2.521 and p = 0.021. Since p < 0.05 then we could conclude that the computer-based learning strategy of free fall movement in experiment group could delve the graphical literacy better (M = 90.28; Std. Error M = 1.60) than the traditional learning conducted in control group (M = 84.05; Std. Error M = 1.92). Error M = 1.92). The elaboration of the learning strategy of free fall movement which adopts PBL, lab inquiry, and the computer could improve the students' graphical literacy in finding and formulating the problems. This method is more appropriate for the beginner because they have no provision about the lecture material. This finding also strengthened by the previous research that the example based learning (EBL) could improve the learning performance better than the problem based learning (PBL), because the students were

given example of problems before they have to delve and to find the problems within the learning (Bambang, et al. 2015b). This founding is line with the reserach report that the use of multimedia has shown a positif impact in improving students' scientific literacy where graph literacy is included (Ardianto & Rubini, 2016).

The data of students' graphical literacy collected from experiment activities, students worksheet , and students' presentation is as shown in Figure 7. It can be seen from the figure that the graphical literacy capability of the experiment group is better than the control group. The information that could be got from the implementation of computer-based learning strategy of free fall movement is that the most fostered capability is the ability to identify the research variable. The advantages of the computer-based learning strategy of free fall movement are: students get a chance to think and to solve the problems based on the fact observed and the concept they have.
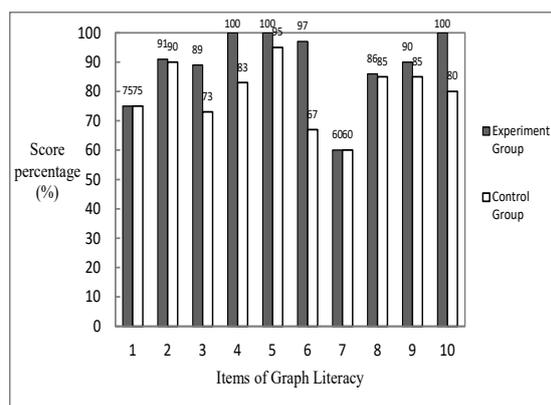

Figure 7. Percentage of the students' graphical literacy which consist of: (1) the students' ability to formulate research questions based on the fact directly observed from the free fall movement device, (2) identifying research variable, (3) operating the device, (4) reading the measurement re-

Tabel 4. Independent sample test for gain score graph literacy with computer-based experiment of free fall movement

Levene's Test of Variances					t-test for Equality of Means			
F	Sig.	t	df	Sig. (2-tailed)	Mean Diff	95% Confidence Interval Of the Difference		
							low	Up
Score graph literacy Equal variances assumed								
.99	.34	2.4	56	.02	6.23		.98	12
Equal variances not assumed								
-		2.5	43.8		.02	6.24	1.18	11

sult, (5) making graph variation, (6) formulating the mathematics equation, (7) interpreting the graph, (8) predicting the graph, (9) concluding the result of experiment, and (10) designing the innovative device of free fall movement.

There were some misconceptions of the students, for instance, that the mass and shape of the object affect the time of falling. Through the exploration of the problem and problem solving through computer-based experiment, students couldwork better. It is because the censor connecting the device and the computer is very sensitive so that the movement could be detected well. It would be different when the students measure the time by suing stopwatch. It will make a significant difference in time. The software helps students to ease the measurement and to present the graph. The number of data would not make the students difficult to analyze. This finding also strengthened by another research that the inquiry learning methods influence the academic ability more than the traditional learning method (Cahyani, et al. 2014; Abdi, 2014).

The strategy which combines PBL, lab inquiry and computer assistance helps students to determine the dependent variable, independent variable, and the control variable. The problem presented in the worksheet helps the students to identify the experiment variable because the problems are presented based on the experiment facts and the initial concept brought by the students. The other improved abilities are operating device, reading the measurement result, making graph, formulating mathematics equation, predicting graph, concluding experiment result, and designing an innovative device. The device of free fall movement is equipped with sensor and software which could foster nine among ten abilities of graphical literacy. The ability to predict has not been optimized yet. It is because the students have no experience in reading graph well. In order to help the students to read and to predict the graph, the students were trained to present their experimental results in the presentation session. This method is more effective to improve the ability of graph interpretation in the kinematics of the students of Physics education, the teacher candidates (Bambang, et al. 2015a; Struck & Yerrick, 2010; Jackson, et al., 1993; Zuker, et al., 2015). In control, class students have used a timing device manually free fall movement using a stopwatch. This leads to students having difficulties in obtaining data accuracy and number of experiments. This situation results highly influential on students' ability to create charts, create mathematical equations and interpret graphs. This is in contrast with the free fall motion-based lab computer lab equipped with sensors and software in order to obtain better data with higher numbers of variations. A motion experiment with free fall sensor-based RAISE program has inspired this study to overcome the constraints of the measurement accuracy interval of free fall motion (Yakubov et al. 2005). Developing research (Pendrill, et al. 2014) on the use Ipad to observe the trajectory of motion can be easily observed through computer graphics presented in this study.

CONCLUSION

The computer-based learning strategy of free fall movement consisted of several steps: The first step was students solve the problems in a worksheet by delving problems, formulating problems, determining the variables, and formulating a hypothesis. The second step was doing the free fall movement experiment which consists of saving and taking the note from the observation table, presenting data, and writing the mathematics equation, interpreting, predicting, and concluding the graph. The third step was discussing the result of an experiment with the other groups and the design of the innovative device of free fall movement.

The computer-based learning strategy of free fall movement could improve the graphical literacy better than the traditional learning. The graphical literacy abilities which could be improved were identifying variables, operating device, reading the measurement result, making graph, formulating mathematics equation, predicting graph, concluding experiment result, and designing an innovative device, while the graphical literacy ability which could not be optimized was the ability to predict the graph because the students have no experience to read graph.

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