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The performance assessment of undergraduate students in physics laboratory by using guided inquiry

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Abstract. The performance assessment of basic physics experiment among undergraduate physics students which includes three stages: pre-laboratory, conducting experiment and final report was explored in this study. The research used a descriptive quantitative approach by utilizing guidebook of basic physics experiment. The findings showed that (1) the performance of pre-laboratory rate among undergraduate physics students in good category (average score = 77.55), which includes the ability of undergraduate physics students' theory before they were doing the experiment. (2) The performance of conducting experiment was in good category (average score = 78.33). (3) While the performance of final report was in moderate category (average score = 73.73), with the biggest weakness at how to analyse and to discuss the data and writing the abstract.

1. Introduction

The laboratory becomes an important part of physics learning [1], in addition to learning how to perform experiments perfectly, the undergraduate physics students are also trained to have good scientific performance [2] and can communicate the results of experiments both orally and in writing [3].

The creativity of undergraduate physics students is needed in scientific performance and communicates the results of the experiment. At the cognitive domain level, the undergraduate physics students are already above the ability to understand (C2) [4]. Experiments can increase the level of critical thinking and effectiveness on learning [4-5], it shows that the cognitive ability of undergraduate physics' students has reached the evaluation stage (C5) [4].

Worksheets or experiment guidebook are needed for designing experiment [7]. In this research used guidebook based guided inquiry. Inquiry becomes a trending topic to improve the performance of undergraduate physics students in conducting experiments [8] to train scientific performance and to improve the critical thinking [9].

The undergraduate physics students' performance are obtained from assessment result of pre-laboratory activity, laboratory activity and experiment report [6][9-11]. Students' preparation improvements for actual activity during laboratory are known from pre-laboratory result [13]. Besides that, students' performance assessment is authentic assessment to assess the students' ability of concept to apply in real situations and train students in having a positive mental attitude [14]. The guidebook based on inquiry using is expected to improve the ability of critical thinking and excellent performance.



2. Method

Participants of the research included 116 undergraduate physics students at State University of Surabaya, Indonesia, which are distributed from four classes, with four topics of basic physics experiment: density, pulley system, mathematical pendulum and spring constant. The research design used a descriptive quantitative approach by using the guidebook of basic physics experiment [7][15]. This is grouped three assessment stages: pre-experiment, conducting experiment and final report. Data was obtained from the score of all stages. It will be analysed in descriptive of the undergraduate physics students' performance as the average score at three stages and then identified their performance capability.

Based on the guidebook of basic physics experiment [7], the scoring system used two types. First, pre-laboratory score and conducting experiment score by giving the check list (✓) on the assessment sheet (Table 1 and Table 2) [7] and then converted into numeric form (Table 3) [7]. While the taking score of the final report by giving the score directly using the number (Table 4) [7]. Second, changing the score to the student's performance (Table 5) [7].

Table 1. Pre-laboratory assessment aspects.

No	Aspects	Good (G)	Moderate (M)	Low (L)
1	Understand of the experiment goals			
2	Understand of the concepts that related to experiment			
3	Identify the variables that must be measured and calculated			
4	Understand of the tool's specification and how to use it			
5	Able to determine the data to be obtained, how to obtain and how to analyse			
Total				

Table 2. Experiment assessment aspects.

No	Aspects	Good (G)	Moderate (M)	Low (L)
1	The ability to set tools correctly			
2	The ability to use and read the scale of the measuring instrument properly			
3	Cooperation among group members			
Total				

Table 3. The conversation score.

Term	Symbol	Score
Good	G	80
Moderate	M	70
Low	L	65

The three stages of physics performance have different assessment aspects, at the pre-laboratory have five aspects assessed (Table 1) [7], whereas at the conducting experiment have three aspects (table 3) [7], and for the final report have six aspects assessed (Table 4) [7].

Table 4. The final report assessment aspects.

No	Aspects	Score
1	The ability to write abstract	
2	The ability to write basic theories that support the experiment	
3	The ability to formulate experimental methods	
4	The ability to analyse the data with uncertainty measurement and answer the questions	
5	The ability to discuss the results of the data	
6	The ability to formulate the conclusions	
Total		

The final score is obtained by each student based on three stages, with different weights. The pre-laboratory has a weight of 2, the conducting experiment has a weight of 3 and the final report has a weight of 5, which all points are divided by 10 (equation 1). The students' performance category can be grouped into 5 levels (table 5) [7].

$$\text{The final score} = \frac{(2 \times \text{Pre-Laboratory}) + (3 \times \text{Conducting Experiment}) + (5 \times \text{Final Report})}{10} \quad (1)$$

Table 5. The range of performance category.

Range	Students' performance
80.1 – 85	Excellent
75.1 – 80	Good
70.1 – 75	Moderate
65.1 – 70	Low
60 – 65	Very low

3. Result and Discussions

3.1. Pre-Laboratory

Pre-laboratory becomes the first assessment stage process of the basic physics experiment. This activity can improve students' performance skills before experiment [11][13]. Based on the five pre-laboratory aspects assessed from four experiment topics obtain results that are not much different. The students' ability to understand the experiment purpose is in a good category, with the score obtained from the four topics, which are 78 from the average of all participants. On the understanding concepts that related to practical topics, the most difficult topic is the spring constant, this is due to the ability of physics students in describe the formula of total constants from various arrangements of spring is not perfect. Based on the score obtained the ability to understand the concepts related to experiment on the topics of spring is in a moderate category. While on the other three topics is in a good category. For the third aspect, the ability of students is in good category, that is identifying the variables that must be measured and calculated.

The fourth aspect of the pre-laboratory stage is to understand of the tool's specifications and how to use it, from this aspect the ability of students is in good category, this is because before doing the experiment, students have been briefed on the tools and experiment tools to be used for basic physics experiment. The Topics of the pulley system get the lowest score compared to the other three topics, the problem is students' performance in a set of pulleys system not perfect. However, from the average score obtained, the category of this topic is good with score 77 (table 6), while the score of the other topics is 79 (table 6).

The ability to determine the data to be obtained, how to obtain, and how to analyse it is the fifth aspect of the pre-laboratory stage. This aspect becomes the basic substance for reporting the results of

the experiment in the final report. In this aspect the topic of the pulley system also gets the lowest score, the score is 74 (table 6) that into the moderate category. The weakness of student performance in this aspect is how to analyse the data, they are confused in managing the data obtained. Both in analyse the calculations and graphs. While on the other topics is in a good category. Overall, based on the average score obtained from each experiment topic in the pre-laboratory stage of student performance is in a good category.

Table 6. Assessment of basic physics experiment.

Stage	Aspect	Score			
		Density	Pulley system	Mathematical pendulum	Spring constant
Pre-laboratory	Understand of the experiment goals	78	78	78	78
	Understand of the concepts that related to experiment	76	77	76	75
	Identify the variables that must be measured and calculated	77	77	79	80
	Understand of the tool's specification and how to use it	79	77	79	79
	Able to determine the data to be obtained, how to obtain and how to analyse	78	74	78	77
	Average	77	77	78	78
Conducting experiment	The ability to set tools correctly	79	77	78	78
	The ability to use and read the scale of the measuring instrument properly	75	79	78	77
	Cooperation among group members	80	80	79	80
	Average	78	79	78	78
Final report	The ability to write abstract	70	73	76	73
	The ability to write basic theories that support the experiment	76	68	77	76
	The ability to formulate experimental methods	75	79	78	78
	The ability to analyse the data with uncertainty measurement and answer the questions	72	76	79	77
	The ability to discuss the results of the data	65	67	74	75
	The ability to formulate the conclusions	71	72	73	71
	Average	71	73	76	75
	Total score	75	75	77	76

3.2. *Conducting experiment*

The second stage of performance assessment of the basic physics experiment is conducting an experiment. In this activity there are three aspects assessed. The first is the ability to set tools correctly. The student's performance in this aspect is in a good category. The second aspect of this stage is the ability to use and read the scale of the measuring instrument properly, on the topic density get the lowest score compared to other topics. this is because the students' performance in reading the measurement tool of length (vernier callipers) is not precise, especially when reading the nonius scales on the vernier callipers. Besides that, how to measure the height of the liquid in the U pipe is not good. One case is when measuring the height of the liquid, they don't read the scale with parallax position. The effects of concave and convex meniscus are not concerned, so the data obtained is not accurate. Based on the value obtain in the second aspect is in a good category.

The third aspect of the conducting experiment stage is cooperation among group members. Theirs average score in third stage is in a good category. It because the task is divided equally and each member do it well.

Overall, the conducting experiment stage is in good category, with the average score is 78 and 79 from four topics. These results show that there is a relationship between the pre-laboratory stage and conducting the experiment stage. This is consistent with the study of Maria et.al that pre-laboratories can improve the preparation skills of practitioners before conducting experiment [13].

3.3. *Final report*

The last stage of basic physics performance assessment is the final report in writing systematics, list in the guidebook of basic physics experiment [7][12]. This stage has six aspects of performance assessment. The first is the ability to write abstract. The results of this obtained: less (70), moderate (73) and good (76). The problem of this aspect is students' ability to choose words and to write important sections in abstract. On the topic of density, students' performance is in a low category, they reveal too many unimportant things in abstract, beside that there are students who write abstracts very short so that the important thing that should be in the abstract they lose. While on the topic system pulley and the spring constant is in moderate category, and for the topic of mathematical pendulum student performance in writing abstract is in good category.

The ability to write basic theories that support the experiment is the second aspect of the final report. The pulley system topic has the lowest score. Most students write the final formula without any explanation, whereas the pulley system has different mechanical advantages based on the pulley position. Based on table 6, the score in this aspect is 68, in low category but in the second aspect of the pre-laboratory stage, understand of the concepts that related to experiment is 77, in good category. These different results were caused different standard from the different assessor in that stages. Therefore, there should be standardization for each point of rubric (aspects and stages) (appendix 1) [16]. In addition, the common mistakes of this aspect are no information about the images, tables and equations.

The third aspect at the final report stage is the ability to formulate experimental methods. The topics of pulley system, mathematical pendulum and spring constant are included in a good category, whereas on the density topic is in moderate category. Students can't determine the density of two different methods. The first method for measuring the density of the solid state uses volume calculation by using the measurement tool of length (vernier callipers and micrometer screw) while the second method uses the volume of spilled water, as for the first liquid method of measuring the volume of the liquid in the measuring cup and the second method using pupa U. With different methods between solids and liquids make students still wrong in formulating experimental methods.

The ability to analyse the data with uncertainty measurement and answer the questions correctly on the fourth aspect has a relationship with the fifth aspect of the ability to discuss the results of data. The students' performance in analysing and discussing the data of the experiment result is less. The greatest hope of performance students on the final report are analysing and discussing of experiment data [7][10]. The data of experiment from the four topics can be made a graph to know the relationship between

variables and also get the point from the equation graph. As well as on the topic of mathematical pendulum, not only using accurate calculations the acceleration of gravity [17][18] but also through graphical analysis. In the fourth aspect, indicate students' critical thinking skill that is in a good category. For the fifth aspect, the problem is the ability of students in connecting the results of experiments with the theory. The lowest score of ability to discuss at the fifth aspect at the topic of density and pulley systems, the score is in low category.

The last aspect of the final report stage is the ability to formulate conclusions. In formulating the conclusions refers to the formulation of the problem and the purpose of the experiment [7]. The students' performance in formulating the conclusion is in moderate category. The problems of this aspect are the low ability of writing conclusion, where they answer the formulation of the problem incorrectly. Based on the average score in the final report stage, only the topics of mathematical pendulum that have good category. Meanwhile, the other three topics are in moderate categories. If the average scores of four topics is in moderate level, so the overall of this aspect at the final report stage is in moderate category. The average score gives a good estimate of the score variety [20]. Thus, all the three stages in laboratory activities, including pre-laboratory, conducting experiment, and final report may increase conception of physics learning [19].

3.4. Final score

Based on the guidebook of basic physics experiment [7], the determination of weights at each stage is clear [equation 1]. From the average data obtained, the physics student in the basic physics experiment can be categorized moderate on the topic of density and the pulley system with a score of 75, while on the topic of mathematical pendulum and spring constant are in good category, the scores are 77 and 76. Overall, the results of physics students' performance are in good category and critical thinking skill is in good category. This is in accordance with the study of Emiliannur et.al, which states that the implementation of a performance assessment model in physics subjects is increasing students' critical thinking disposition [21].

4. Conclusion

The performance assessment of the students in the physics laboratory using guided inquiry show that in the pre-laboratory stage is in a good category (average score = 78) and for the conducting experiment stage is in a good category (average score = 78) while in the final report stage is in a moderate category (average score = 74). The performance of physics students in the basic physics experiment is in moderate category on the topic of density and pulley system, whereas on the topic of mathematical pendulum and spring constant are in good category. Overall, the results of physics students' performance and critical thinking skills are in good category.

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Appendix

1. Rubric of pre-laboratory assessment

No	Aspect	Performances' indicator		
		Low	Moderate	Good
1	Understand of the experiment goals	Experiment goal don't based on relation between independent variable and dependent variable	Experiment goal based on relation between independent variable and dependent variable, but with help	Experiment goal based on relation between independent variable and dependent variable
2	Understand of the concepts that related to experiment	Student can understand basic concepts, can't derive the equation and misconceptions	Student can understand basic concepts, derive the equation and misconceptions	Student can understand basic concepts, derive the equation and aren't misconceptions
3	Identify the variables that must be measured and calculated	Student can't identify independent, dependent and control variable	Student can identify independent, dependent and control variable, but don't based on experiment goal	Student can identify independent, dependent and control variable based on experiment goal
4	Understand of tool's specification and how to use it	Student can't choose the tools and specification, but according to the experiment	Student can choose the tools but the specification don't according to the experiment	Student can choose the tools and specification according to the experiment
5	Able to determine the data to be obtained, how to obtain and how to analyse	Student can't determine the data, how to obtain it and analyse	Student can determine the data and analyse but how to obtain it with help	Student can determine the data, how to obtain it and analyse

2. Rubric of conducting experiment assessment

No	Aspect	Performances' indicator		
		Low	Moderate	Good
1	The ability to set tools correctly	Student can't string up the tool and modify the circuit	Student can string up the tool and modify the circuit incorrectly	Student can string up the tool and modify the circuit correctly
2	The ability to use and read the scale of the measuring instrument properly	Isn't doing calibration and don't read the scale with parallax position	Doing calibration but don't read the scale with parallax position	Doing calibration and read the scale with parallax position
3	Cooperation among group members	The task isn't divided equally and it is done by certain dominant student	The task is divided equally but each group member doesn't do it	The task is divided equally and each member do it

3. Rubric of final result assessment

No	Aspect	Performances' indicator				
		60	65	70	80	85
1	The ability to write abstract	The abstract consists of experimental goals and methods, the conclusions are incorrect	The abstract consists of experimental goals and methods, but the analysis and conclusions are incorrect	The abstract consists of experimental goals, methods, and conclusions the analysis result are incorrect	The abstract consists of experimental goals, methods, results analysis and conclusions are incorrect	The abstract consists of experimental goals, methods, results analysis and conclusions
2	The ability to write basic theories that support the experiment	Basic theory is too general, no derive equation and don't give information of the equation, table and figure	Basic theory is specific but no derive equation and don't give information of the equation, table and figure	Basic theory is specific and give information of the equation, table and figure, but there is no derive equation	Basic theory is specific and derive equation and don't give information of the equation, table and figure	Basic theory is specific and derive equation and give information of the equation, table and figure
3	The ability to formulate experimental methods	Experiment method isn't based on goals and not written in a row	Experiment method based on goals, not written in a row and point form	Experiment method based on goals, not written in a row and paragraph form	Experiment method based on goals, written in a row and point form	Experiment method based on goals, written in a row and paragraph form
4	The ability to analyse the data with uncertainty measurement and answer the questions	Student can't analyse data, calculate uncertainty and answer question incorrectly	Student can't analyse data and calculate uncertainty, but answer question	Student can analyse data and calculate uncertainty, but not answer question	Student can analyse data, calculate uncertainty and answer question incorrectly	Student can analyse data, calculate uncertainty and answer question correctly
5	The ability to discuss the results of the data	Students can't connect the result of data with theory and don't give explanation	Students can't connect the result of data with theory, but give explanation	Students can connect the result of data with the scientist result and not give explanation it	Students can connect the result of data with the scientist result and explanation it incorrectly	Students can connect the result of data with the scientist result and explanation it correctly

No	Aspect	Performances' indicator				
		60	65	70	80	85
6	The ability to formulate the conclusions	All of the conclusion aren't answer the formulation of problems and incorrectly	some of the conclusion aren't answer the formulation of problems but incorrectly	some of the conclusion aren't answer the formulation of problems but correctly	some of the conclusion are answer the formulation of problems correctly	All of the conclusion are answer the formulation of problems correctly

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