

EMPIRICAL AND THEORITICAL STUDENT WORKSHEET DEVELOPMENT IN VECTOR RESULTANT ANALYSIS

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ABSTRACT

Vector is the basic concept in physics learning. Several studies have stated that participants' students experience difficulties in the form of the inability to reason and experience misconceptions about the basic concept of vectors. The difficulties underlie this research to conduct measurement of the understanding ability of students use the student worksheet which was developed based on an empirical and theoretical reviews on vector material. The steps of laboratory activities in the development are adjusted with the guided discovery learning model. The development model used in this research is ADDIE (Analysis, Design, Develop, Implement, and Evaluate). The analysis techniques used a paired sample t-test to see whether the increase is significant or not. The result of this research get an increasing significant score, between the mean pre-test score (41) and mean post-test score (66) by using a scale of about 0 to 100. The research findings provide ideas to develop the students' worksheets based on the theoretical and empirical reviews on the dynamic fluids topic.

KEYWORDS: Vector; understanding ability; empirical and theoretical reviews; student worksheet; ADDIE

1 INTRODUCTION

Vector concepts and calculation methods are at the core of physics learning that underlie most of the topic discussed as an early introduction to learning. Some examples of physics learning topics that require knowledge of vectors are motion and change, Newton's forces and laws, momentum, mechanical energy, and magnets and electromagnets. Based on these examples, in the law of Conservation of Energy it is estimated that several concepts are interrelated in certain topics and their understanding requires a higher level of thinking (Govender & Gashe, 2016). This shows that the vector concept is one of the basic concepts in Physics that is important to understand correctly. Correct understanding of vectors concepts can indirectly prepare thinking in studying further physics concepts that require an understanding of vectors.

Several research results stated that students' inability to reason on the basic concepts of vectors. Students' inability can occur due to failure in the abstraction process. The abstraction

process is influenced by the tasks performed by students, the media used by students, and between students and teachers (Widada et al., 2019). Therefore, to improve students' reasoning on the basic concepts of vectors, it is important to provide learning media that are able to help the expected process of reasoning ability through their understanding ability. One form of learning media that can be used to help improve the abstraction process so that students' understanding ability are achieved by conducting laboratory activities. Laboratory activities can be carried out if a study has facilities in the form of study guides such as student worksheets. The student worksheets needed to overcome these problems can be developed based on empirical and theoretical reviews (Wartono et al., 2018). The stages of laboratory activities in the student worksheets can be adapted to the guided discovery learning model (Rosdiana, 2020). The development of student worksheets which is carried out with the guided discovery learning model is expected to be able to stimulate students' understanding abilities.

One of the focuses in this research is the development of student worksheets. Student worksheets is included in learning media and contains an explanation that provides guidance on the activities that will be carried out by students in learning (İnan & Erkuş, 2017). Student worksheets needed to be developed to fit the applied learning model. The student worksheets that is in accordance with the guided discovery learning model is based on empirical and theoretical reviews (Rosdiana, 2020). Empirical and theoretical reviews are also needed in a learning that has a learning goal to improve students' understanding abilities (Wartono et al., 2018). Student worksheets based on empirical and theoretical reviews is applied gradually. The first stage of student worksheets presents a syntax that will produce empirical findings (experimental results). Meanwhile, in the second stage, student worksheets presents a syntax that will produce theoretical discoveries which can be in the form of formula derivation or other. The results of the comparison of findings that are reviewed empirically and theoretically can build good students' reasoning abilities through the understanding abilities (Malang et al., 2019).

Then, how students understand when using student worksheets combined with mathematical analysis in both empirical and theoretical reviews is the core of this research. Several studies have found that students have difficulty understanding in some basic subjects, such as when determining acceleration, Newton's gravitational, Force (Bollen et al., 2017) and advanced subjects, such as electricity and magnetism (Kim, 2017). Some physical quantities are classified as vector quantities and are very important for students to gain a good understanding of vector algebra and other discussions about vectors (Susac et al., 2018). An understanding of vectors is necessary as a basis for studying all advanced or applied subjects. Measuring students' understanding ability through the use of student worksheets developed in this study is by giving a multiple choice test in the form of questions that are not much different but with different levels of difficulty. The same type of many question that are given have the aims to measure how much students understand about the resultant and the magnitude of the vector direction.

2 MATERIALS AND METHOD

The research design used the model of ADDIE (*Analysis, Design, Development, Implementation, and Evaluation*) that proposed by Dick and Carry in 1996. ADDIE is one of the model that destined for development research.

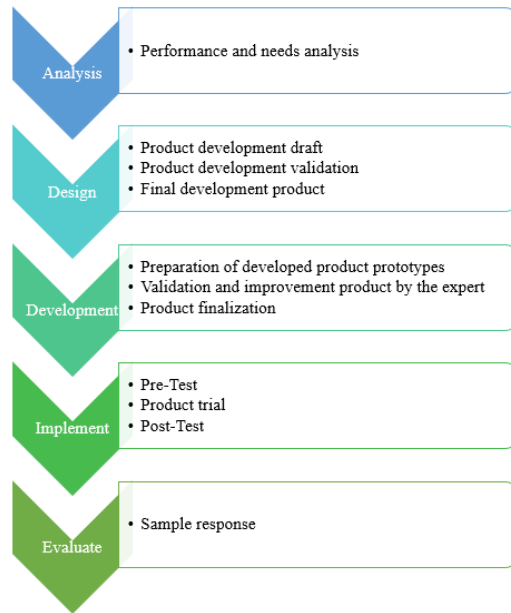


Figure 1: The Stages of ADDIE

The performance analysis is carried out to find out and clarify whether the performance problems faced require solutions in the form of implementing learning programs or improving learning media. While, the needs analysis is a necessary step to determine the abilities or competencies that need to be learning by students to improve performance or learning achievement. From the analysis stage, products in the form of worksheets and learning instruments such as questions to be tested can be designed in the form of documents. Then, the student worksheets as a product and the instrument can be validated by experts. Validation is needs for improving the product and instrument before applied. The implementation stage is used to obtain quantitative data by applying student worksheets as a product and providing pretest and posttest in the form of instruments. The quantitative research used one group pretest-posttest (Dimitrov & Rumrill, 2003) which called as experiment group. (See Table 1) Then, the evaluation of the product implementation can be done.

Table 1: One Group Pretest-Posttest

Pre-Test	Treatment	Post-Test
O	X	O

Pretest is carried out before the treatment. The treatment carried out was in the form of applying the student worksheet based on empirical and theoretical reviews developed on vector material. The post-test has the same questions as the pretest to ensure the significance level of increase in students' understanding ability. However, to avoid the influence of fresh learning memories from students, the final test was carried out a week after being given a treatment.

The research sample consisted of 26 students of Science Education in Islamic University of Lamongan. The sample were taken from 2nd and 4th semester students. The research produce the quantitative data. Quantitative data was obtain from measuring students' understanding ability through pretest and posttest activities.

3 SIMULATION RESULTS AND DISCUSSION

The data came from ten multiple choice questions with the focus of discussion in the form of resultants and vector directions. The focus of the discussion was chosen only from two topics, namely the resultant and vector direction of the vector because they wanted to see the consistency of the answers from students regarding the solutions given to each question. The questions have been tested for validity and reliability both through mathematical calculations and through experts before being given to students. The questions was given as a test on 35 respondents and produced questions that were categorized as valid and reliable with a standard deviation value 1.9.

The result of data collection showed pre-test average score of 41 and post-test average score of 66, as in figure 2.

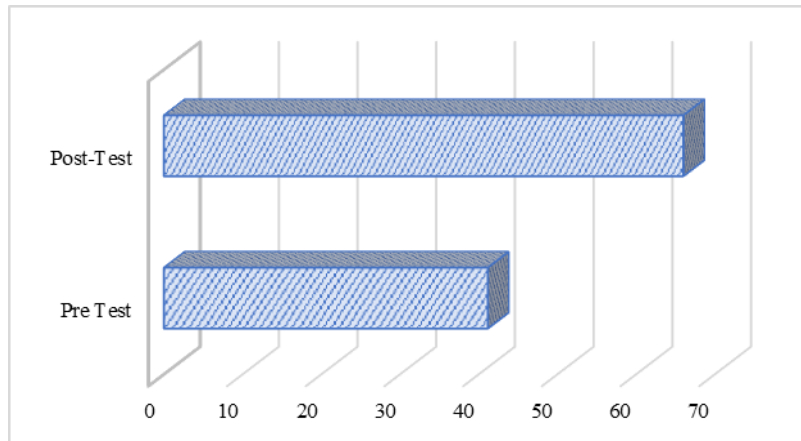


Figure 2: The Average Score of Pre-Test and Post-Test

The data obtained show that the average post-test score obtained by 26 research samples is higher than the average pre-test score. Based on the data that has been obtained, a test was carried out normality and homogeneity of data. The normality test is used to determine whether the data collected is normal or not and as a determinant of the analysis technique to be used. Meanwhile, the homogeneity test is used to see whether the data collected is homogeneous or not. The normality and homogeneity test was assisted by SPSS Version 25. The results of the normality tests and homogeneity tests were in Table 2 and Table 3. Based on the Shapiro Wilk tests, the level of significance taken is $\alpha = 0.05$. If the table have the sig. $> \alpha$, then the data is normally distributed and homogen.

Table 2: Tests of Normality

	Shapiro-Wilk		
	Statistic	df	Sig.
Pre-Test	.924	26	.056
Post-Test	.940	26	.132

Table 3: Tests of Homogeneity of Variance

		Levene Statistic	df1	df2	Sig.
Learning Score	Based on Mean	.420	1	50	.520
	Based on Median	.302		50	.585
	Based on Median and with adjusted df	.302		49.327	.585
	Based on trimmed mean	.394		50	.533

The normality test used is the Shapiro-Wilk because the sample data is less than 50 data. The results of the normality test on the pre-test value have a significance value of 0.056 while the post-test value has a significance value of 0.132. A significance value of more than 0.05 can be said to be normal data, so it can be said that the data is normal worthy. While the homogeneity test also shows a value of 0.533 which concludes that the data is homogeneous.

Furthermore, of the data collected can be concluded as normal and homogeneous data, then the analytical technique that can be used in this study is the paired sample t-test or paired t-test, to see whether there is a significant or not. Paired t-test shows a significance value of less than 0.05 (See Table 4) which concludes that there is a significant increase in the use of Student Worksheets that is being developed.

Table 4: Paired Sample Test

		Paired Differences				t	df	Sig. (2-tailed)	
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre-Test and Post-Test Score	-25.000	8.602	1.687	-28.475	-21.525	-14.819	25	.000

In addition to an increase in student learning outcomes through the Student Worksheets developed as in several related previous studies (Fisika et al., 2016; Rosdiana et al., 2019; Wartono et al., 2018). Other findings that can be used in this study are the factors that cause students' obstacles in solving problems. The main factor that students experience difficulties in solving problems is the existence of misconceptions that are maintained both before and after the treatment is given. The misconception occurs in the use of mathematical equations in determining the resultant vector.

Figure 3 shows the results of the pre-test and post-test of the same respondent. In the results of the pre-test and post-test, respondents still maintain their misconceptions about the resultant vector. The misconceptions that are maintained can affect learning outcomes (Syukran Ervina Rhahim, 2015), especially in understanding and reasoning (Barniol et al., 2013) of students about the vectors that exist in the next subject such as momentum and impulse (Syukran Ervina Rhahim, 2015) and Newton's Law (Mongan et al., 2020). Students who still maintain misconceptions can be concluded that they have not been able to understand what has

been learned through laboratory activities using Student Worksheets based on empirical and theoretical reviews on vector material. Figure 4 shows that in laboratory activities both empirically (practical/experimental discovery) and theoretically (deriving equations), the purpose of each activity is to determine the magnitude of the direction and vector resultant.

4. Dua buah gaya masing-masing 10 N dan 15 N membentuk sudut 60° . Besar resultan kedua gaya tersebut adalah ...

a. $5\sqrt{3}$ N
 b. $5\sqrt{17}$ N
 c. $5\sqrt{19}$ N
 d. $5\sqrt{2}$ N
 e. 20,6 N

5. Dua vector masing-masing 3 m dan 8 m dengan satu titik tangkap, ternyata besar resultannya sebesar 7 N. besar sudut apit antara kedua vector tersebut adalah ...

a. 30°
 b. 45°
 c. 60°
 d. 90°
 e. 120°

6. Dua buah gaya sama besar yaitu 10 N membentuk sudut 120° satu sama lain. Selisih kedua vector tersebut adalah ...

a. 0 N
 b. 10 N
 c. $10\sqrt{2}$ N
 d. $10\sqrt{3}$ N
 e. 20 N

(a)

4. Dua buah gaya masing-masing 10 N dan 15 N membentuk sudut 60° . Besar resultan kedua gaya tersebut adalah ...

a. $5\sqrt{3}$ N
 b. $5\sqrt{17}$ N
 c. $5\sqrt{19}$ N
 d. $5\sqrt{2}$ N
 e. 20,6 N

5. Dua vector masing-masing 3 m dan 8 m dengan satu titik tangkap, ternyata besar resultannya sebesar 7 N. besar sudut apit antara kedua vector tersebut adalah ...

a. 30°
 b. 45°
 c. 60°
 d. 90°
 e. 120°

6. Dua buah gaya sama besar yaitu 10 N membentuk sudut 120° satu sama lain. Selisih kedua vector tersebut adalah ...

a. 0 N
 b. 10 N
 c. $10\sqrt{2}$ N
 d. $10\sqrt{3}$ N
 e. 20 N

(b)

Figure 3: The Answers of Pre-Test (a) and Post-Test (b) from one responden

Tabel Pengumpulan Data

(Percobaan 1)

No.	F1 (N)	F2 (N)	θ ($^\circ$)	$F_1^2 + F_2^2 + 2 F_1 F_2 \cos \theta$	F_r^2	F_r
1.	1 N	1 N	30°	$1^2 + 1^2 + 2 \cdot 1 \cdot 1 \cos 30^\circ$	3,2	1,7
2.	1 N	2 N	30°	$1^2 + 2^2 + 2 \cdot 1 \cdot 2 \cos 30^\circ$	7,2	2,6
3.	2 N	3 N	30°	$2^2 + 3^2 + 2 \cdot 2 \cdot 3 \cos 30^\circ$	22,6	4,7

(Percobaan 2)

No.	F1 (N)	F2 (N)	θ ($^\circ$)	$F_1^2 + F_2^2 + 2 F_1 F_2 \cos \theta$	F_r^2	F_r
1.	1 N	1 N	60°	$1^2 + 1^2 + 2 \cdot 1 \cdot 1 \cos 60^\circ$	4	2
2.	1 N	1 N	45°	$1^2 + 1^2 + 2 \cdot 1 \cdot 1 \cos 45^\circ$	2,8	1,6
3.	1 N	1 N	120°	$1^2 + 1^2 + 2 \cdot 1 \cdot 1 \cos 120^\circ$	2	1,4

(a)

* Jika persamaan 1, 2, dan 4 disubstitusikan ke dalam persamaan 3 maka akan diperoleh:

$$R^2 = (F_1 + F_2 \cos \alpha)^2 + (F_2 \sin \alpha)^2$$

$$R^2 = F_1^2 + 2F_1 F_2 \cos \alpha + F_2^2 \cos^2 \alpha + F_2^2 \sin^2 \alpha$$

$$R^2 = F_1^2 + F_2^2 (\cos^2 \alpha + \sin^2 \alpha) + 2F_1 F_2 \cos \alpha \dots (5)$$

* Karena, $\cos^2 \alpha + \sin^2 \alpha = 1$, maka persamaan 5 menjadi:

$$R^2 = F_1^2 + F_2^2 + 2F_1 F_2 \cos \alpha$$

* Dari 6 persamaan diatas, dapat diperoleh persamaan untuk mencari besaran besaran vektor: Resultan: $R = \sqrt{F_1^2 + F_2^2 + 2F_1 F_2 \cos \alpha}$

(b)

Figure 4: Determine the Equation of Vector Resultant Magnitude Through the Student Workshseets by Empirically (a) and Theoretically (b)

4 CONCLUSION

The learning outcomes measured in this study show how the cognitive improvement of students' abilities is assessed. The learning outcomes obtained can be specified into students' understanding abilities (Alam, 2020; Alghadari & Herman, 2018). Based on the data that has been collected, student learning outcomes are concluded to have experienced a significant increase. Conclusions about increasing learning outcomes can be categorized as increasing

students' understanding abilities (Brahmia et al., 2020) in using Student Worksheets based on empirical and theoretical reviews on vector material. Meanwhile, data showing the value of learning outcomes can show the ability to educate students (Novia & Riandi, 2017). Based on research data showing an increase in students' understanding abilities using the developed student worksheets, the student worksheets can be used for further research on different materials such as dynamic fluids and others.

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