

Design of Student Worksheet Teaching Materials for Viscosity of Biodiesel, Dexlite, and Pertamina Dex with Falling Ball Measurement Technique

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Abstract

The lack of teaching materials use, especially in viscosity topics, has decreased students' knowledge and analytical skills in measurement. The research aimed to design a Student Worksheet (LKPD) for viscosity topics to assist and train students in measuring the viscosity of fluids. The fluids used in the experiment were biosolar, dexlite, and pertamina dex, considering that these fuels are among the most significant commodities and widely used in Indonesia. Additionally, the viscosity of diesel fuel is an important property affecting combustion and engine injection. This research employed a quantitative method using laboratory experiments to measure the viscosity values of biosolar, dexlite, and pertamina dex using the falling-ball method. The research findings were utilized to develop the LKPD teaching materials. The results showed that the viscosity values of biosolar fuel, dexlite, and pertamina dex were 3.651 cP; 3.579 cP; and 3.004 cP; respectively. These results differed slightly from the literature but were still deemed suitable for the LKPD teaching material design. The title of the LKPD teaching material used was "Viscosity of Biosolar Fuel, Dexlite, and Pertamina Dex Using the Falling-Ball Measurement Technique," and it followed the format of a cover, usage instructions, summary of the material, laboratory assignments, and questions.

Keywords: falling-ball method, fuels, student worksheet (LKPD), viscosity

INTRODUCTION

Petroleum is a non-renewable natural resource owned by Indonesia. Petroleum has a major influence on Indonesia because it is one of the pillars of the Indonesian economy and society, which depends on using petroleum (Lendeng, Sugiarso, & Rumagit, 2021). According to the Downstream Oil and Gas Regulatory Agency (BPH Migas), Indonesia's fuel oil consumption annually reaches 50 million kilo liters, both subsidized and non-subsidized (Risdiyanta, 2015). This is due to the growth in vehicle volume, which results in increased demand for fossil fuels. The largest contributor to the increase in vehicle volume is diesel vehicles. That is because diesel vehicles are considered to have higher engine durability,

efficiency, and characteristics when compared to gasoline vehicles (Syarifudin & Syaiful, 2019). The demand for diesel fuel increases every year, which causes the country of Indonesia to import diesel oil to meet domestic demand (Syarifudin & Syaiful, 2019). Indonesia imports diesel oil to meet the domestic market due to the limited production of diesel oil in Indonesia. Diesel fuel is used by diesel engines (Adh-dhuhaa, 2016).

Indonesia, through Pertamina, releases four types of fuel for diesel engines, namely diesel, biodiesel, dexlite, and pertamina dex, with different cetane values. Diesel fuel and biodiesel have a cetane value of 48, dexlite has a cetane value of 51, and pertamina dex has a cetane value of 53 (Cappenberg, 2017). The CN value of diesel engine fuel is also influenced by its essential properties.

One of the important properties of diesel engine fuel is viscosity. The physical property of viscosity is an essential property for diesel engine fuels. This viscosity property shows the resistance of the fluid to its flow due to friction in the engine part of the liquid moving from one place to another, affecting the injection to the combustion chamber. If the viscosity is too low, it can result in a leak in the fuel injection pump. However, if the viscosity is too high, the speed of the flow to the combustion chamber will be slow (Tarigan, 2012).

Viscosity is something that expresses the size of the viscosity of the fluid or liquid. Fluids with high viscosity values will inhibit objects inserted into the fluid. High-viscosity fluids are also difficult to flow (Lumbantoruan & Yulianti, 2016). Some fluids flow quickly and slowly. A fluid that flows quickly means it has a small viscosity value. Meanwhile, liquids that flow slowly have a large viscosity value (Sutiah et al., 2018). The viscosity of the liquid in diesel engine fuel can be measured by methods taught in physics learning, namely the practicum of determining the viscosity value of a liquid (Asih et al., 2022). One method used in determining a liquid's viscosity value is the falling ball method. The calculation used in this method uses the Stokes law equation. (Ardiansyah, 2017).

Diesel engine fuel can be an example of fluid to explain viscosity material in physics learning. Based on the research results by Yudhitiara, Hindarto, & Mosik (2017), the level of ignorance of students' concepts of viscosity material is 72.5%; the rest still have misconceptions and uncertainty about viscosity material. The results of this study explain that most students still do not understand the material of viscosity and its units. According to Damayanti et al (2018), the factors that cause students' lack of understanding of viscosity material are the way students think, lack of learning references, learning systems, and lack of in-depth knowledge and experience. Based on observations, it shows that student textbooks only contain viscosity material and Stokes' law in general. While the viscosity of diesel engine fuel is still not included in the material, either in the form of practicum assignments, examples, and practice questions. In addition, the results of interviews with students show minimal understanding of the fuel quality for diesel vehicles. So that these problems

can be overcome by providing appropriate learning resources. Teaching materials are one of the learning resources that play an essential role in improving the quality of learning. To utilize teaching materials as learning resources, they must be well-designed and equipped with attractive illustrations (Nurbaeti, 2019).

Furthermore, viscosity material will be organized into teaching material designs so that students can understand and quickly learn this knowledge. According to Magdalena et al (2020), teaching materials are a set of learning materials that contain learning materials arranged systematically and interestingly to achieve the expected goals. Teaching materials are an essential part of determining the quality of learning. The design of teaching materials must pay attention to the model to ensure the effectiveness of teaching materials in education because teaching materials and the learning process are linear (Cahyadi, 2019). The focus of teaching materials in this research is the Learner Worksheet (LKPD), which contains the viscosity practicum of the falling ball method on biodiesel, dexlite, and Pertamina dex fuels. This is done because students need to know how to measure fluid viscosity such as biodiesel, dexlite, and Pertamina dex fuels. In addition, students can also understand how to measure viscosity with the falling ball method.

METHOD

The type of research conducted in this research is a type of quantitative research with laboratory experimental methods, namely research measuring the viscosity value of biodiesel, dexlite, and Pertamina dex fuels with the falling ball method. Then, the results of the study were used as material for the design of teaching materials to be made by researchers. The type of teaching material design is teaching materials in the form of Learner Worksheets (LKPD). In this research, there are two variables, namely, the independent variable and the dependent variable. The independent variables in this study are biodiesel, dexlite, and Pertamina dex. The dependent variable in this study is the viscosity value of biodiesel, dexlite, and Pertamina dex fuels and the design of teaching materials.

This research was carried out with several stages, as seen in Figure 1.

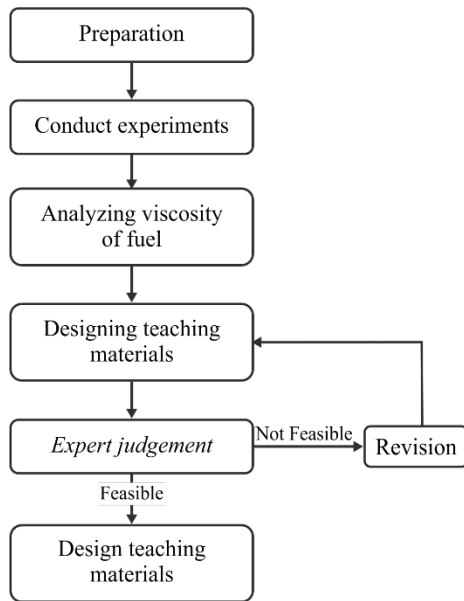


Figure 1. Research flow chart

The first stage is preparation. At this stage, the researcher collects the tools and materials for the experiment. The tools needed for the falling ball method are three marbles of different sizes, liquid collection tubes, measuring cups, pycnometers, balances, and stopwatches. The materials needed are three types of fuel, namely 2 liters of biodiesel, dextrite, and Pertamina Dex.

The second stage is to conduct experiment. This stage begins by measuring the density of the iron ball and each fuel. The density value is obtained by using the formula $\rho = \frac{m}{V}$. The tools used to measure fuel density are a pycnometer and a balance sheet. The tools used to measure the volume of the marble ball are a measuring cup filled with water and a balance sheet. Measurements were taken three times.

Next, the viscosity of the fuel was measured using the falling ball method. This method uses a liquid collection tube with a duct tape mark at each end to calculate the travel time of the falling ball in the liquid. Measurements were taken with different ball sizes three times.

The next step is to analyze the viscosity of the fuel. A marble ball is dropped into a collection tube that contains fuel. When the ball is dropped, it will

produce a terminal velocity using the following formula

$$v_t = \frac{2r^2g}{9\eta} (\rho_b - \rho_f)$$

If s is the distance traveled by the ball and the time taken is t , then:

$$\frac{s}{t} = \frac{2r^2g}{9\eta} (\rho_b - \rho_f)$$

To calculate the fuel viscosity coefficient (η), the formula is:

$$\eta = \frac{2r^2gt(\rho_b - \rho_f)}{9s}$$

Furthermore, it begins making research products through LKPD teaching material designs. The topics in the design of LKPD teaching materials are cover, instructions for use, material summary, and practicum assignments.

The draft teaching materials that have been made are then reviewed by the supervisor. If the teaching material is not feasible, it must enter the revision stage and return to the stage of making teaching material designs. If the teaching material is feasible, then the teaching material enters the next stage.

Teaching materials are feasible if the supervisor has assessed them and can be used as the final product of this research in the form of LKPD teaching material design.

Data obtained from laboratory experiments in the form of average values of viscosity coefficient (η) of biodiesel, dextrite, and Pertamina Dex fuels. The average value of the viscosity coefficient (η) comes from repeated measurements three times. The average formula used is as follows.

$$\bar{x} = \frac{x_1 + x_2 + x_3}{3}$$

Description:

\bar{x} : average value

x_1 : 1st measurement value

x_2 : 2nd measurement value

x_3 : 3rd measurement value

RESULT AND DISCUSSION

This research aims to design teaching materials viscosity of biodiesel, dextrite, and Pertamina Dex with falling ball measurement

technique. The product of the teaching material design of this research is the Learner Worksheet (LKPD), which contains a summary of the material about viscosity of the falling ball method and practicum assignments. This research has two stages, namely the fuel viscosity measurement stage and the LKPD teaching material design stage.

The fuel measurement stage begins by measuring three different-sized marbles' mass, radius, volume and density. The three marbles are labelled as marble 1, marble 2, and marble 3. The measurement data can be seen in Table 1.

Table 1. Data table for calculating the density of ball marbles

Types of objects	m (g)	r (cm)	V (cm ³)	ρ_b (g/cm ³)
Marble 1	3	1.2	1	3
Marble 2	6	1.6	2	3
Marble 3	24	2.6	8	3

The next measurement is to measure the density of each fuel, namely biodiesel, dextrite, and Pertamina dex. This measurement uses a pycnometer with a capacity of 50 ml. To get the density value of the fuel, the mass and volume values of each fuel are required. The measurement data can be seen in Table 2.

The next measurement was to measure the viscosity coefficient of biodiesel, dextrite, and Pertamina dex. The tube is filled with fuel and then marked with black duct tape at 10 cm from each end. This measurement is done by dropping a marble ball into a tube that has been filled with fuel and then recording the time on the distance travelled. The measurement data can be seen in Table 3.

Table 2. Fuel density calculation data table

Fuel type	T (°C)	V (cm ³)	m (g)	ρ_f (g/cm ³)
Biosolar	25	50	43	0.86
Dextrite			42	0.84
Pertamina dex			40	0.8

Based on the research results in Table 3, it shows that the viscosity value of biodiesel is greater than dextrite and Pertamina dex. The biodiesel viscosity value obtained in this experiment is 3.651 cP. This result is not much different from the literature of Setyaningsih et al. (2018), which shows that the viscosity value of biodiesel is 3.525 cP. The viscosity values of dextrite and Pertamina dex obtained in this experiment are also not much different from the existing literature. According to Bachrani (2019), the viscosity value is 3.45 cP. The experimental results obtained were dextrite of 3.579 cP. In comparison, the viscosity value of Pertamina dex according to Haryono (2017), is 3.39 cP. The experimental results obtained are Pertamina dex of 3.004 cP.

When compared to the cetane value of each fuel, it can be concluded that the viscosity value of the fuel is inversely proportional to the cetane value. So, the greater the cetane value, the smaller the viscosity value. Damayanti (2011) explains that fuel viscosity significantly affects engine performance. If the viscosity is too small, it can cause the pumping pressure against the fuel to decrease, which can cause leakage (wear). Conversely, if the viscosity is too large, it can aggravate engine performance, which causes incomplete combustion. Therefore, the viscosity value of the fuel is significant to know so that the engine performance can work properly.

Table 3. Fuel viscosity coefficient calculation data table

Fuels types	ρ_f average (g/cm ³)	ρ_b average (g/cm ³)	r_b average (cm)	distance (cm)	T (°C)	t (second)	coefficient of viscosity (P)	$\eta_{average}$								
								(P)	(cP)							
Biosolar	0.86	3	1.2	100	25	1.34	0.00899	0.00922	3.651							
						1.42	0.00953									
						1.36	0.00913									
			1.6			1.27	0.01515	0.01515								
						1.29	0.01539									
						1.4	0.01491									
			2.6			2.51	0.07908	0.08517								
						2.87	0.09042									
						2.73	0.08601									
						1.23	0.00833			0.00842						
Dexlite	0.84	3	1.2	100	25	1.29	0.00874									
						1.21	0.00820									
						1.35	0.01626									
			1.6			1.33	0.01602	0.01626								
						1.37	0.01650									
						2.56	0.08141									
			2.6			2.61	0.08300	0.08268								
						2.63	0.08363									
						Pertamina dex	0.8		3	1.2	100	25	1.04	0.00718	0.00796	3.004
													1.21	0.00835		
1.21	0.00835															
1.6	1.29	0.01582	0.01533													
	1.21	0.01484														
	1.25	0.01533														
2.6	1.77	0.05733	0.06683													
	2.58	0.08356														
	1.84	0.05959														

The difference between the research results and the literature is due to inaccurate time calculations that must be repeated several times and the focus needed to stop the stopwatch when the ball has crossed the predetermined line mark. In addition, when the marbles are dropped, they collide with the tube wall, which affects the time of the ball rate, so it is necessary to repeat until the marbles do not collide with the tube wall.

The next stage is the design of LKPD teaching materials. This teaching material design is entitled "Viscosity of Biosolar, Dexlite, and Pertamina Dex with Falling Ball Measurement Technique". Compiled using A4 paper with a size of 21 cm x 29.7 cm. The LKPD design image is shown in Figure 2.

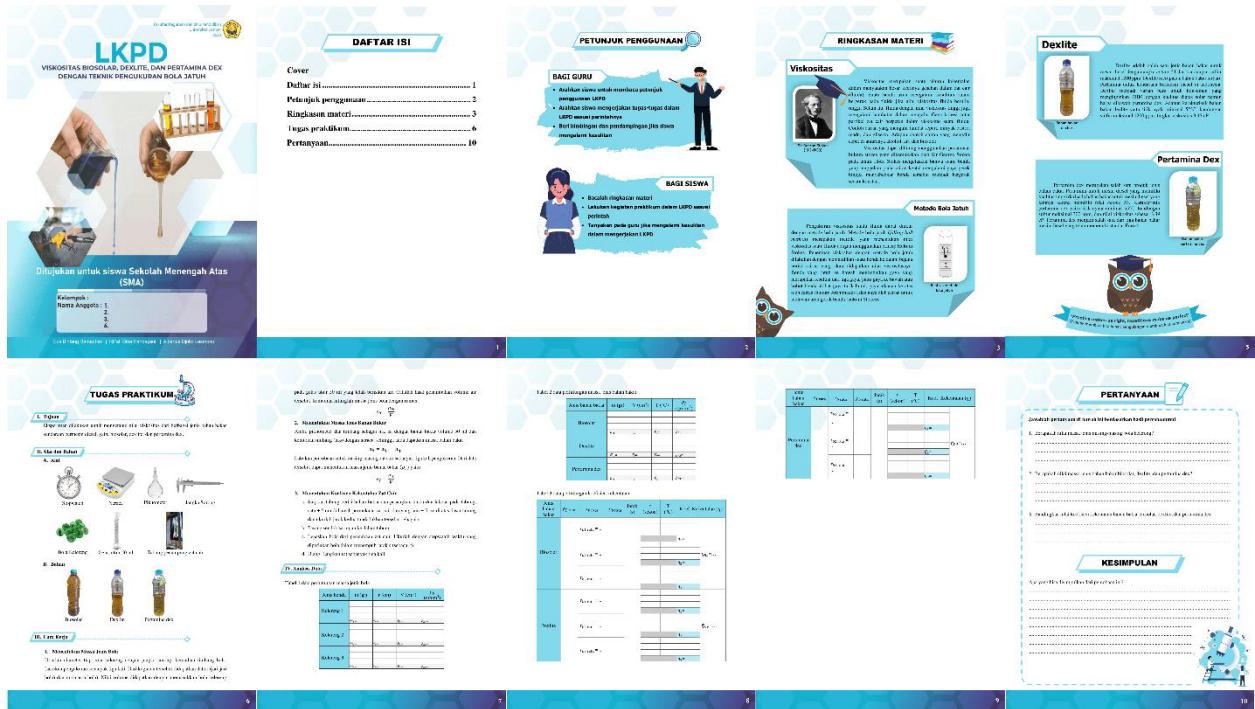


Figure 2. LKPD Design

The design of LKPD teaching materials that have been completed is validated through the expert judgment stage. This stage is carried out by a team of experts, namely the supervisor, as evidenced by the expert judgment statement letter. At this stage, the expert team will provide suggestions and comments to improve the design of the teaching materials prepared. This stage is needed to determine the suitability of the teaching materials that are compiled. After making revisions to the suggestions and comments from the expert team, the design of LKPD teaching materials with the title "viscosity of biosolar, dexlite, and pertamina dex with falling ball measurement technique" was declared feasible.

The LKPD teaching material design component consists of a cover, instructions for use, material summary, practicum tasks, and questions.

a. Cover

The cover of this LKPD design is a blend of blue and white with a picture of a thick liquid being poured accompanied by a picture of refueling in a vehicle and a test tube, illustrating that the contents of this LKPD are related to measuring the viscosity or viscosity of a liquid,

namely in the form of biodiesel, dexlite, and pertamina dex fuels. The cover part has the title of the LKPD, namely viscosity of biosolar, dexlite, and pertamina dex with falling ball measurement technique. The author's name, supervisor, and university of jember logo are also listed on the front cover. The LKPD teaching material design component consists of a cover, instructions for use, material summary, practicum tasks, and questions.

b. Instructions for Use

This section explains the use of LKPD for teachers and students. The use of LKPD for teachers is directing students to read instructions for use, directing students to work on LKPD as instructed, and providing guidance if students experience difficulties. Meanwhile, the use of LKPD for students is reading the instructions for use, doing the activities in the LKPD as instructed, and asking questions if they have difficulty.

c. Material Summary

This section contains brief material about viscosity and the methods used when working on LKPD tasks. The viscosity material contained

in the summary is the definition of viscosity, examples of slow and fast-flowing liquids, and the inventor of the equation formula to find the value of viscosity, sir george stokes. In addition, this material summary also explains the measurement method used to work on this LKPD task, namely the falling ball method measurement. In this section, the force generated in the falling ball method is briefly explained.

d. Practicum Tasks

This section: objectives, tools and materials, work methods, and data analysis. In the purpose section, the direction of this experiment is explained, namely knowing the viscosity value of the fluid used, namely biodiesel, dexlite, and pertamina dex. The tools and materials section shows pictures of what materials and tools are needed in this experiment so that students understand the form of tools and materials. The work method section explains the stages of conducting experiments measuring viscosity using the falling ball method. Starting with determining the density of the ball, then determining the density of the fuel, and determining the coefficient of viscosity of the liquid. In the last section, a data analysis contains a calculation data table. Students are directed to fill in the measurement results in the table to make it easier when calculating data.

e. Questions

In this section, students are asked questions about the conclusions of the experiments that have been carried out. This question is given so students can conclude and interpret the relationship to the final results of the experiments that have been carried.

CONCLUSION

Based on this research, it is concluded that the design of LKPD teaching materials results from expert judgment so that it can be continued with the manufacture and use of LKPD. The format of the teaching materials starts from the cover, instructions for use that show how to use the LKPD

for both students and teachers, a summary of the material with an explanation of viscosity along with the formulas and liquids used, practical tasks equipped with stages of how it works, questions for students about the results of their practicum, and conclusions to train students to describe the results of the practicum that has been done.

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