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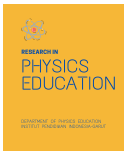

ARTICLE

Low-cost measurement light intensity and efficiency of the lamp For school purposes in science experiment

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Abstract

The purpose of this research is to assist science teachers in carrying out experiments in science classes, particularly physics classes, to ascertain the optimal light intensity and efficiency of various lamp types made of inexpensive materials that are related to scientific concepts. The purpose of this study was to develop a practical learning technique based on experiments to measure the lamp's energy efficiency and light intensity. Three different types of bulbs were used in this research experiment: CFL, LED, and incandescent. Students select a lamp after the experiment based on observations of light intensity and calculations of the lamp's efficiency using a solar power meter and efficiency equation. The light intensity of the LED lamp shows the highest value with 18,66W/m2 rather than Compact Fluorescent lamp with 15,05% and incandescent lamp with 0,02%. While the efficiency of the LED lamp is 52,6%, the CFL is 26,89%, and the incandescent lamp is 11,26% Novelty: There is not a lot of study on the measurement of light intensity and the calculation of lamp efficiency using inexpensive materials for science-related student experiments.

Keywords: School Experiment, physics Experiment, lamp Light Intensity, science Experiment

1. Introduction

There are two distinct approaches to doing science: theory and experiment (Arıcı and Yılmaz 2020). Laboratory activity is the most important thing in learning science. It appears that neither curriculum developers nor teachers agree that science courses need to involve a substantial amount of laboratory work (Hodson 1988). The core components of building knowledge in science are lab activities (Kang and Wallace 2005). Through laboratory exercises, students need to apply science theory in various areas. Practical exercises and laboratory work are essential components of the educational process for students (Estriegana, Medina-Merodio, and Barchino 2019). In laboratory activity, students not only apply science theory through experiments. Yet, students carry out experiments by the guidelines, write up a report, analyze the data, and interpret the findings (Kapilan, Vidhya, and Gao 2021). Hence, in conducting science lessons needs to conduct experiments for students. Experimental validation is crucial for supporting theoretical ideas in the physical sciences, such as physics, biology, and chemistry. science as an application, which refers to using science to comprehend the ideas

surrounding it (Rini and Aldila 2023). Latifah (2015) stated experimental design is designed to improve critical thinking abilities.

Science lab experiments as educational opportunities (Hofstein and Lunetta 2004). The student could apply their experiences in laboratory activity to their daily life. Inquiry-based learning may improve physical science students' performance (Wolf and Fraser 2008). Science Process Skills (SPS) are acquired by students through the use of the Inquiry-Based Learning Approach (IBL) (Joy and Dinah 2017)(. Students gain the ability to recognize and formulate problems using scientific knowledge and procedures, critical thinking, and reasoning abilities, all through the application of the inquiry method (Sahintepe, Erkol, and Aydogdu 2020). The inquiry-based learning technique has a major impact for critical thinking skills on students (Duran and Dökme 2016). Another research evaluated a guided inquiry-based chemistry activity with ninth-grade students who had never participated in guided inquiry-based learning previously (Orosz et al. 2023).

Students that use technology can learn and retain topics more effectively (Raja and Nagasubramani 2018). In this era, a lot of technology affecting laboratory activity in school. Students who are not present can utilize a web-based interface to manage the equipment and gather data (Koretsky et al. 2008). Virtual laboratory only used to laboratory that has not enough tools and materials as the alternative. Even though, there are a lot of technology supporting the student conducting the virtual laboratory. Curricula and educational material are crucial in igniting and sustaining young people's interest in science and technology (El-Emadi, Said, and Friesen 2019)(.

There are many technology has developed. One of the technologies that is always used by people in the world is lamp. the technology of lamps has produce with a lot of types. Light-emitting diode (LED) lights and compact fluorescent lamps (CFLs) are the two primary technologies used in the production of lamps for household lighting (Di Mauro and Raciti 2014). However, the incandescent lamps still use in several purposes such as the farming or another purposes. In recent years, light-emitting diodes (LEDs) have been employed for lighting more and more, and their use has increased substantially in response to the global need for energy savings (Li, Chen, and Chen 2011). A compact fluorescent lamp (CFL) is a tube-shaped fixture that operates on the basis of sending a discharge arc via a gas (Kumar, Jain, and Bansal 2003)(. According Chignell et al., (2008) Compact fluorescent lights (CFLs) have a longer rated life and consume less power. halogen, compact fluorescent, or light-emitting diodes (LED) light bulbs—often termed energy-saving light bulbs (Frondel and Lohmann 2011). The electric incandescent filament bulb was only one of Edison's 1093 patents, he needed to create a system in order to make electric lighting practical (Moran 2010).

However, there are no research measuring the light intensity and calculate efficiency the different types of lamp that always used in society using the low-cost material for student as experiment purpose relate with science subject. This research constructed the experiment from three types of lamps which are LED lamps, incandescent lamps, and CFL lamps. At the end of the experiment, students decide on the lamp based on the experiment which observes the light intensity and calculates the efficiency of the lamp with low-cost material. This research aims the science teacher to conduct the experiment in science subject, especially in physics to determine the best light intensity and efficiency of the types of the lamp with low-cost material, which relate with science concept. Then, teacher could assess the ability of the student in fulfill the worksheet and their argument in choosing the efficiency of the lamp in the worksheet that teacher develop by themselves. Therefore, this research has benefited in students' perspective in choosing lamps based on efficiency for sustainability. Also, this research could be a reference as future research for developing the experiments and the reference for the teacher which would to use this experiments to their students relate with science topic and sustainability action.

The research problems in this research are what is the result of the light intensity in LED lamp, Compact Fluorescent, and incandescent lamp? and how much the efficiency of the LED lamp, Compact Fluorescent Lamp, and incandescent lamp? Which one has the best efficiency?

2. Research Method

This research conducted to establish an experiment-based practicum learning approach to determine the light intensity and efficiency of the energy from the lamp. This approach seeks to determine the rationale behind the technology selection made in their environment. In practicum learning, Students can discuss and share their opinions on a variety of subjects and apply scientific ideas that they have learned from practice or observation (Sormin, n.d.).

The experiment was designed from three types of lamps that are always used by people. This experiment used an incandescent lamp, a compact fluorescent lamp, and a light-emitting diode lamp. the design of the experiments conducting try and error. Three types of lamp that chosen has the same power input. While the the light intensity of the lamp come from the result of measuring the distance between the lamp and the solar power meter to measure the light intensity. The variable of this experiments encompassed: Independent variable (i.e. The distance between the solar power meter and the lamp); Dependent variable (i.e. Light intensity); and Control variable (i.e.The power of the lamp (15 Watt)).

There were several steps undertaken in the present study.The steps we have conducted were: finding novelty, determining objectives, designing experiments, providing a judgment by experts, revising, trying a trial and error, collecting and analysing data, finishing the research.

2.1 Light intensity

Light intensity is the measurement of the level of the brightness of the lamp. The light intensity could measure the brightness of the sunlight using lux meter and measure the brightness of the lamp using the solar power meter with the unit is W/m2. In this study, we measure the light intensity of the lamp. The figure below show the illustration of the lamp which show the light beam.

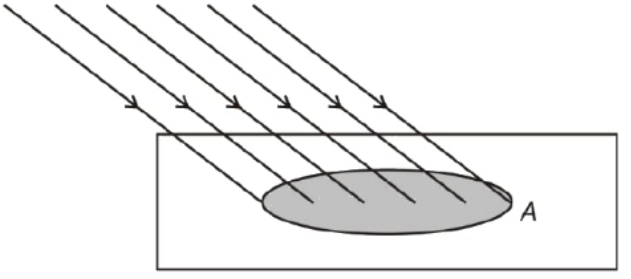

Figure 1. The ilustration of the light beam of the lamp

The illustration show the light beam and show the image in the surface. Also the light intensity could lighter is direct proportional with the power of the lamp. Therefore, we could conclude the equation of the light intensity by the equation below.

$$I = \frac{P}{4\pi R^2} \tag{1}$$

2.2 Tools and materials

This research used the tools and material to support the experiment. The tools and materials that need is solar power meter, 50 cm ruler, three kind of lamps (LED lamp, CFL lamp, Incandescent lamp), and desk lamp.

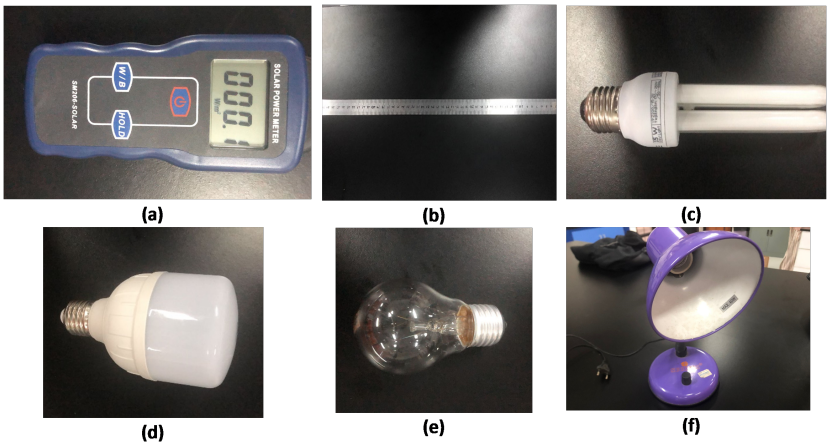

Figure 2. Tools and material, (a) solar power meter, (b) 50 cm ruler, (c) Compact Fluorescent Lamp, (d) Light Emitting Diode Lamp, (e) Incandescent Lamp, (f) desk lamp

2.3 Procedures

The research conducted in physics laboratory in Universitas Pendidikan Indonesia. We measuring the light intensity using solar power meter. The area of the measurement of the light intensity should be in the dark place to minimize the error due to another light comes into the solar power meter. To turn on the lamp, we used the desk lamp to make the replacement of the lamp easier. Then, the solar power meter put into the source of the lamp by the ruler is put under the light ray begin. To make easier to imagine, the set up experiment of the research show below.

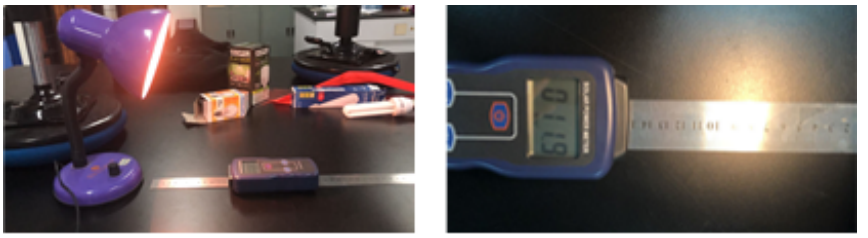

Figure 3. The set up of the experiment

The experiment conducted three times with the same procedure and different lamp. Also, the light intensity measure in 5 cm, 10 cm, 15 cm, 20 cm, 25 cm, 30 cm, 35 cm, 40 cm, 45 cm, and 50 cm. The result would be fill in the tables and input into the graph to compare three types of the lamps. The table of measurement of the light intensity of the lamps show below.

2.4 Data analysis

The result of measurement the light intensity would input in Microsoft excel to make the graph from all of the types of the lamp. Then, the result of each distance would calculate by the average. Therefore, we could get the result of of the light intensity in one type of lamp. after getting the average of the light intensity, we could calculate the power from this equation formula below.

$$\eta = \frac{P_{in}}{P_{out}} \tag{2}$$

This measurement result used as the power output to calculate the efficiency of the lamp. After measuring the power output, this experiment calculate the efficiency from the lamp by the equation formula below. The power input in this equation used the power in the lamp. which all of the types of the lamp used 15 watt. The result of the efficiency of all the types lamp would compare to find out the most efficient lamp. The most efficient lamp comes from the biggest value of the result.

3. Result of the research

3.1 The light Intensity in LED, CFL, and incandescent lamp

The measurement of the types of lamp compare the light intensity with the same power input (watt) of all the lamps and the distance of measurement between the source of the lamp and the solar power meter as the control variable. The result would be show in separated Table 1, Table 2, and Table 3.

Table 1. The light intensity of LED Lamp

Distance (cm)	Light Intensity (W/m2)
5	84,1
10	46,8
15	22,9
20	11,8
25	6
30	4,6
35	3,6
40	2,8
45	2,3
50	1,7
Average	**18,66**

As the result in table 1. Show the light intensity of LED lamp. The result show the inversely proportional between the distance and the light intensity. However, another result of the Compact Fluorescent Lamp show in Table 2 with the same method.

Table 2. Light intensity of Compact Fluorescent Lamp

Distance (cm)	Light Intensity (W/m2)
5	67,3
10	38,4
15	19,2
20	9,4
25	5,2
30	3,9
35	2,7
40	2,1
45	1,4
50	0,9
Average	**15,05**

The light intensity measurement of Compact Fluorescent Lamp show the lower value than LED lamp. While, the measurement of the incandescent lamp show in Table 3 below.

Table 3. The light intensity of Incandescent Lamp

Distance (cm)	Light Intensity (W/m2)
5	43,7
10	18,5
15	9,2
20	4,2
25	2,8
30	2,1
35	1,3
40	0,6
45	0,24
50	0,03
Average	**0,02**

The light intensity of the LED lamp show the highest value rather than Compact Fluorescent lamp and incandescent lamp. The average of incandescent lamp show the significant different between the LED lamp and the CFL. It mean the light intensity of the LED lamp is the brightness lamp rather than the incandescent lamp and CFL. While the comparison show the light intensity of CFL is brighter than CFL. The figure below show the comparison of the light intensity in the graph between the incandescent lamp, CFL, and LED lamp.

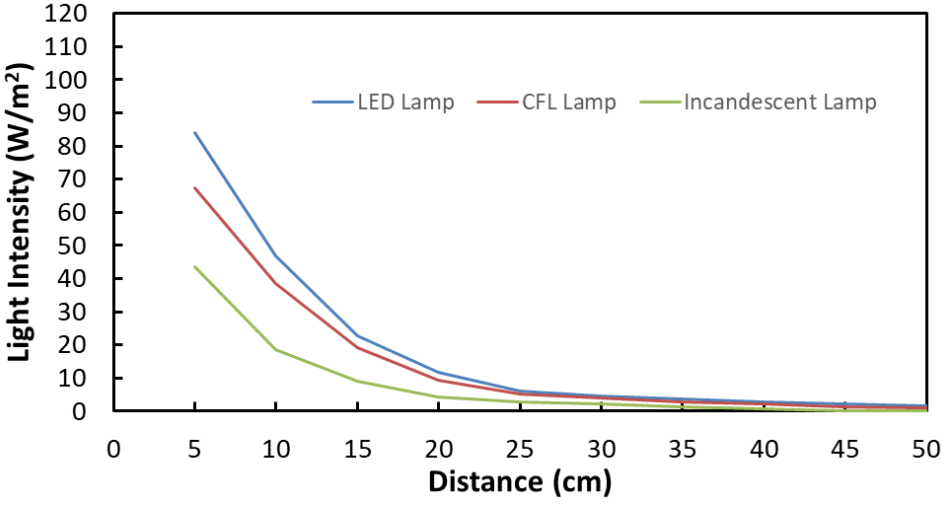

Figure 4. The graph of the light intensity of three lamps

The graph show the in the x-axis is the distance in each 5 cm, while the y-axis show the light intensity in W/m2 unit. The graph show the light intensity is decrease in the number of the distance is increase. It means the trend-line show the graph going down.

3.2 The efficiency of the LED, CFL and incandescent Lamp

After measuring the efficiency of the three types of the lamp. The light would measure the efficiency to determine the best lamp and the effective lamp to use in daily life. Before calculate the efficiency, the lamp need to calculate the power output. The light intensity would take from the average of

the ten times measurement of different distance in every types of lamp. While, the distance need to convert to meter as international standard unit. While the result of the power output would divide into power input which are the power of the lamp as the control variable, which 15 Watt. Therefore, here is the equation that would use. Here is the result of the power output to of the types of the LED lamp show in the table below.

Table 4. The power ouput and the efficiency of LED lamp

Distance (cm)	Power Output (Watt)	Efficiency (%)
5	2,64	17,60
10	5,88	39,19
15	6,47	43,14
20	5,93	39,52
25	4,71	31,40
30	5,20	34,67
35	5,54	36,93
40	5,63	37,51
45	5,85	39,00
50	5,34	35,59
Average	**5,32**	**52,6**

From the Table 4 above, the efficiency of the lamp show the average 52,6% from the 10 distance of measurement from light intensity by using solar power meter. While, the CFL show the efficiency from the graph below.

Table 5. The power output and the efficiency of CFL

Distance (cm)	Power Output (Watt)	Efficiency (%)
5	2,11	14,09
10	4,82	32,15
15	5,43	36,17
20	4,72	31,48
25	4,08	27,21
30	4,41	29,39
35	4,15	27,69
40	4,22	28,13
45	3,56	23,74
50	2,83	18,84
Average	**4,03**	**26,89**

Here is three tables show the power output and the efficiency of three types of lamp. The result show the LED lamp is the most efficient with the average 52,6%, while the Lowest efficient lamp is the incandescent lamp with average 11,26%.

4. Discussion

The reason of the LED lamp is the greatest lamp in this research with the highest light intensity and efficiency. The efficiency mean the percent of the efficiency is the energy that used. As the example, the efficiency of LED lamp is 52,6%. It means the 52,6% energy used, while the rest

Table 6. The power output and the efficiency of incandescent lamp

Distance (cm)	Power Output (Watt)	Efficiency (%)
5	1,37	9,15
10	2,32	15,49
15	2,60	17,33
20	2,11	14,07
25	2,20	14,65
30	2,37	15,83
35	2,00	13,33
40	1,21	8,04
45	0,61	4,07
50	0,09	0,63
Average	**1,69**	**11,26**

become the energy loss. The energy loss could become heat. The incandescent lamp produce heat from energy loss less than CFL and LED lamp. Therefore, the incandescent lamp produce more heat rather than CFL and LED lamp. So that, the incandescent lamp always used in farming purpose such as to warm the livestock or the egg of the livestock. This finding has same result with finding of another research. When compared to an equal incandescent light bulb, the higher the wattage of the CFL, the greater the amortization of manufacturing energy and, thus, the lifetime energy savings (Soneji 2008). Typically, only around 5% of the energy input is converted into light by incandescent light bulbs (Frondel and Lohmann 2011). Another findings state that energy-saving bulbs are more efficient than incandescent ones (Ndinechi et al. 2012).

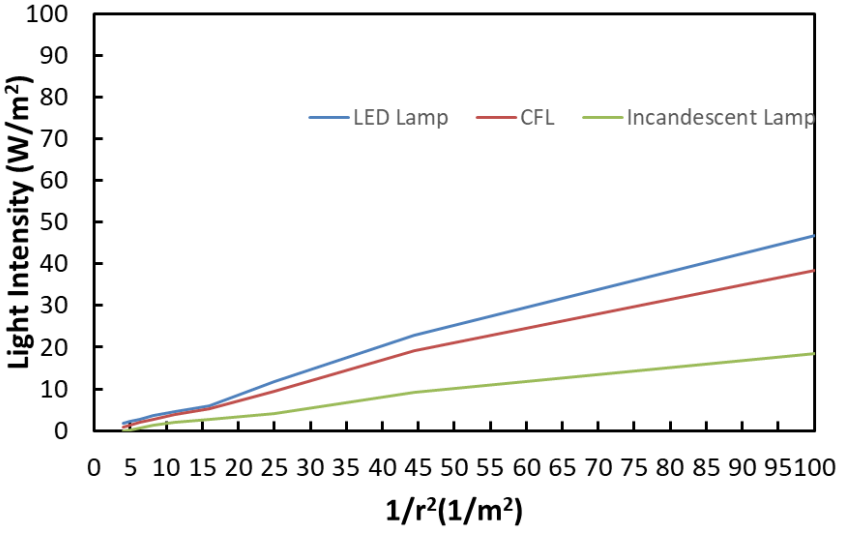

Figure 5. The equation of trend-line Light intensity ($1/r^2m^2$)

Since an incandescent light bulb has a luminous effectiveness of only 15 lm·W-1, it is considered a legacy light source due to its thermal radiation (Toyoda et al., 2019). Incandescent lights can be used to save energy, and there are several options available when less light is acceptable, use lower wattage lamps; when a shorter lifespan is preferred, use greater efficiency lamps; when refectories

lamps are used instead of normal lamps; and when transformer fixtures that support low voltage lamps are used (Li, Chen, and Chen 2011). Incandescent bulbs are being replaced by CFLs and LEDs in a variety of lighting applications in order to conserve energy (Lim et al. 2013).

Another finding in Hudallah et al., (2021) state the lux of the LED lamp is brighter than the CFL lamp and the lamp and ambient heat of the CFL lamp has higher temperature than the LED lamp. LEDs have the potential to be the perfect alternative to incandescent lights because of their extended lifespan and understated design (Jacob 2009)(. LED bulbs are mercury-free and reusable (Musa et al. 2013).

This experiment could use as the experiment in school science course. In Indonesian curriculum (Kurikulum Merdeka), this experiment relate with the science course in 8th grade in chapter Vibrations, Waves, and Light. The sub chapter that are related is Light. The objective in this sub chapter is Analyzing phenomena wave propagation light. In this sub chapter, the student to be expected to analyzing the phenomenon of light wave propagation. However, the teacher could innovate the material from this experiments because this experiment has related with daily life for students. Another Indonesian curriculum state the basic competences for chapter Lights and Optics. Table 8. shows the basic competences in Indonesian curriculum in chapter Light and Optics. Specifically, the basic competences in terms of the Curriculum 2013 dealing with Light and Optics are presented in this quotation.

> Analyzing the properties of light, image formation on flat and curved planes, and its application to explain the process of human vision, insect eyes, and the working principles of optical instruments [Point 3.12].
> Presents the results of experiments on shadow formation on mirrors and lenses [Point 4.12].

5. Conclusion

Finding the most efficient lamp for school purpose is successful. The student could find out the best lamp for sustainability purpose by only solar power meter. In this research, the most bright lamp is LED lamp with the average light intensity 18,66 W/m2 and second lamp is CFL with the average light intensity 15,05 W/m2, and the last brightness lamp is incandescent lamp with the average light intensity is 0,02 W/m2. While, the efficiency of the LED lamp is the most efficient in this research with 52,6% and the CFL has efficiency 26,89%, and the incandescent lamp has the efficiency 11,26%. This research is used as the student experiment, the student could calculate the efficiency with low-cost tools. Also, the student could have argumentation about the used of the types in the lamp such as which the type of the lamp used in their home, farm or etc by using physics equation principle. This research not cover all of the findings, the limitation of this research is the research only find out the light intensity of the lamp and calculate for the efficiency. This research do not mention the lumen and the exact number for the power of the lamp. The power of the lamp getting from the information of the package. Therefore, the lumen will different one with another brand, even though it is the same power. Also, this research only develop the experiment and not apply to student. The future research if this research as the reference could apply this research to student and find out the student responses for this research with different types of lamp or different power of the lamp and could be use another tools to find the light intensity besides solar power meter, which more advances.

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