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Development of a Simple and Low-Cost Light Diffraction Props for Teaching and Learning Optics during Covid-19 Outbreak

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Abstract: The Covid-19 pandemic forces the learning process to be carried out in a blended learning manner that combines face-to-face and synchronous learning.This study aims to share the implementation of experiments that we have carried out during the Covid-19 pandemic, especially on optics material for high schools involving prospective physics teacher students. This study uses a descriptive research method with the research subject being Physics Education students, FKIP University of Lampung, with a sample of 2017 Physics Education students who are taking Optics lectures.The results of this study are in the form of optical learning media that have been designed by students while attending lectures with distinctive characteristics made from low cost material and using simple technologies. This study proves that physics experiments can be carried out by utilizing learning media in the form of low-cost material teaching aids. In addition, physics experiments can be carried out directly without a complicated preparation. Learning activities that utilize this kind of teaching aids will certainly train students' science process skills, procedural knowledge and conceptual knowledge that is improved through hands-on activities and mind-on activities during the learning process.

Keywords: blended learning, teaching aids, science process skills, hands-on activity, mind-on activity

Abstract: *Pandemi Covid-19 memaksa proses pembelajaran harus dilaksanakan secara blended learning yang menggabungkan pembelajaran face to face dengan sinkronous. Penelitian ini bertujuan untuk sharing pelaksanaan eksperimen yang telah kami lakukan selama pandemi Covid-19 khususnya pada materi optika untuk sekolah menengah yang melibatkan mahasiswa calon guru fisika. Penelitian ini menggunakan metode penelitian deskriptif dengan subjek penelitian yaitu mahasiswa Pendidikan Fisika FKIP Universitas Lampung, dengan sampel mahasiswa Pendidikan Fisika angkatan 2017 yang sedang mengikuti perkuliahan Optika. Hasil penelitian ini berupa media pembelajaran optik yang telah dirancang oleh mahasiswa selama mengikuti perkuliahan dengan ciri khas berbahan murah serta memanfaatkan teknologi-teknologi sederhana. Penelitian ini membuktikan bahwa percobaan fisika dapat dilakukan dengan memanfaatkan media pembelajaran berupa alat peraga berbahan murah. Selain itu percobaan fisika dapat dilakukan secara langsung tanpa perlu adanya persiapan yang cukup rumit. Aktivitas pembelajaran yang memanfaatkan alat peraga semacam ini tentu akan melatih keterampilan proses sains peserta didik, melatih pengetahuan prosedural dan konseptual yang terasah melalui kegiatan hands-on activity dan mind-on activity selama proses pembelajaran.*

Keywords: *pembelajaran campuran, alat peraga, keterampilan proses sains, aktivitas langsung,, aktivitas pikiran*

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▪ INTRODUCTION

Physics is a subject that consists of mathematical calculations based on physical concepts that are bound together, this causes physics in some studies to be considered a subject that categorized as difficult and load heavily by teachers in delivering material to students (Colak, 2020). Physics learning can be improved through an active approach that allows students to be involved in learning activities such as interact, experiment, and demonstrate (Dorrío et al., 2017). Snetinová et al., (2018) states that experimental activities in learning can be categorized into two parts, namely experiments conducted by teachers and experiments carried out by students themselves. The part one that has a greater impact on students is the second way (active involve). Through active involvement such as experiment, students can gain more knowledge compared to learning activities dominated by teachers. In addition, learning that prioritizes experimental activities can improve students' science process skills (Reynolds, 1991). This is in accordance to the studies carried out by Hıra (2017) that scientific knowledge can be divided into two domains, namely content knowledge and process skills. Content knowledge includes theories, models, facts, and principles. Process skills include procedural knowledge used in science such as observation, formulating hypotheses, and taking measurements.

Science process skills have an important role in learning activities because they have a close relationship with the student's cognitive development (Brotherton and Preece, 1995; Harlen, 1999). Science process skills help students to develop understanding, identifying and utilizing evidence as problem solving efforts, and decisions making (Ambross et al., 2014). Gagne (1965) divides science process skills into two domains, namely basic and integrated science process skills. Basic science process skills provide an intellectual foundation in science such as providing an overview of the object being observed. Examples of these basic science process skills are observing, classifying, measuring, and predicting. Integrated science process skills are used as skills in conducting experiments or solving problems, for example identifying, determining variables, making tables and graphs, determining relationships between variables, interpreting data, manipulating materials, formulating hypotheses, and designing investigations, and drawing conclusions (Walters and Soyibo , 2001). Science process skills indicators must be relevan to the cognitive, affective, and psychomotor domains in Bloom's taxonomy. The existence of these three domains makes it easier for teachers to design and develop appropriate learning methods, and can enable students to improve their cognitive and psychomotor abilities (Duan, 2006). Determine relationships between variables, interpret data, manipulate materials, formulate hypotheses, and design investigations, and draw conclusions (Walters and Soyibo, 2001).

Physics learning cannot be separated from investigation activities through hands-on activities and mind-on activities. Hands-on activity is an active learning process that encourages students to find, develop, stimulate creative and critical minds, and motivate students (Dhanapal and Shan, 2014). Hands-on experiments according to Trnova (2015) can support the components of creative pedagogy, develop teacher creativity (creative teaching), and student creativity (creative learning). Klopfer (1990) states that hands-on experiments can allow students to obtain the results of their observations and measurements directly. In physics learning, hands-on experiments have advantages for both teachers and students because experimental activities can be carried out even with minimal preparation. The materials commonly used in hands-on experiments are easy to find, in contrast to experimental activities in general laboratory which have more complicated procedures and preparations (Vollmer & Möllmann, 2012).

Hands-on in general means learning by experience. Students handle scientific instruments and manipulate the objects they are studying (Ateş & Eryilmaz, 2011). Hands-on activities are learning by doing something, which allows students to think critically in conducting investigations during learning (Sadi & akıroğlu, 2011). Hands-on activities can affect interest in learning, where student interest in learning will increase when learning is carried out with hands-on activities (Holstermann *et al.*, 2010). Minds-on activity mindss-on science activity includes the use of higher order thinking, such as problem solving compared to the hands-on activity (Ateş & Eryilmaz, 2011). Minds-on activity is a cognitive domain in the learning process like anything we know, including perception, memory, and imagination (Gazibara, 2013). Minds-on activities can help students collect and process information through activities such as reading, listening, writing, asking, observing, and expressing opinions (Aini and Dwiningsih, 2014). Teachers who are accustomed to using hands-on activities and minds-on activities in learning will result in higher student learning outcomes (Acharya, 2018).

Things that must be considered in experiments or investigations, namely applying conceptual knowledge and procedural knowledge. Conceptual knowledge is knowledge related to the facts of a concept, as well as applicable principlesDe Jong and Ferguson-Hessler (1996).Procedural knowledge includes the ability to read and produce graphs and tables, carry out construction. Procedural knowledge can be seen through the ability of students to connect the problem solving process with the problems given by the teacher, as well as how they use the problem solving process correctly.Al-Mutawah et al. (2019).This conceptual knowledge serves to add information in solving problems, while procedural knowledge is the ability or action to manipulate the learning process. Procedural knowledge includes knowing how to identify, limit, select, and solve problems, thereby helpingstudents make a connection from one state to another. Procedural knowledge refers to the ability of students to determine when and how to apply a learning procedure, as well as the skills to perform activities efficiently, flexibly and accurately.Rittle-Johnson and Alibali (1999)states that procedural knowledge can affect the understanding of concepts from students, because it can help students identify and minimize their misunderstandings.

The Covid-19 pandemic, which forces learning to be done online or hybrid at various levels of education, makes a teacher must be able to prepare learning more maturely. One of the recommended lessons to be implemented is: discovery-based inquiry learning such as the process of collecting data, interpreting data and drawing conclusions according to Pedaste et al. (2015) can be implemented by utilizing the latest technology. Krasnova & Shurygin (2020) revealed that technological advances such as computer-based learning help students to be able to exchange information without any distance restrictions. In addition, blended learning is learning that combines face to face and synchronous learning. The teacher's role in blended learning is to develop learning with various representations, expressions, and involvement in designing and supporting students in learning (Walker and Keeffe, 2010). Technology is an important tool in blended learning because it can increase flexibility and the possibility of reusing learning information, however technology cannot replace the importance of interaction between students, as well as students and teachers.

Physics learning often requires additional media to explain the material through experimental activities, the material generally has abstract data that is difficult to analyze manually such as optical material. Experimental activities can be carried out through synchronous activities, especially using zoom meetings, and google meetings. Experimental activities can be carried out using simple teaching aids made from cheap (Ateş & Eryilmaz, 2011). Teaching aids are used to make it easier for teachers to develop learning in the classroom (Shabiralyani et al., 2015). Teaching aids as learning media such as factory-made practicum tools such as the Integrated Instrument Box (KIT) generally have a permanent structure, this creates other problems in the learning process. Media that has a permanent structure is not good if used in learning that prioritizes the development of experimentation, creativity, and student skills. This is because the media that has a permanent structure cannot be changed, both the components and the materials used(Khoa and Bang, 2019). Criteria that need to be considered in preparing teaching aids according to Vollmer and Möllmann, (2012) that is; 1) The materials used are widely available, easy to obtain, and relatively inexpensive, 2) the preparation is simple, 3) its use does not require a long time, and 4) its use can trigger feelings of enthusiasm and surprise in students.

This study aims to share the implementation of experiments that we have carried out during the Covid-19 pandemic, especially on optics material for high schools involving prospective physics teacher students. The design of teaching aids that are requested to be developed must be made of cheap materials and can utilize simple technologies. It is intended that the teaching aids produced by prospective teachers can be applied in blended learning.

▪ METHOD

This research uses descriptive research method. In this study, the population consisted of prospective students for physics teachers at the University of Lampung. The sample in this study was taken using a simple random sampling technique with the characteristics of students having satisfactory grades in the Optics course. Based on these characteristics, eight students were taken consisting of two groups. Each group has their own props that are made during the lecture activities.

This research was conducted by conducting three stages of descriptive research. Each stage of the research is as follows: (a) Collecting data, at this stage it is done by collecting props that have been made by students, then taking data using these props, (b) Analyzing the data, at this stage the data that has been obtained analyzed whether in accordance with the theory or not, (c) interpreting the data, at this stage the data that has been analyzed is then interpreted so that conclusions can be drawn. This research was carried out in 2019 for one semester which coincided with the teaching of the Optics course in the Department of Physics Education.

The research instrument in this study is an observation instrument. The type of data in this study is secondary data in the form of learning data for the Optics course, as well as learning media produced by students while taking the Optics course. This research data was obtained by taking several samples of learning media that had been designed by students during the Optics lecture. After collecting the data, the data were analyzed using descriptive analysis to describe the raw data (quantitative) into a form that is easier to understand (descriptive).

▪ RESULT AND DISCUSSION

The results of this study are in the form of optical learning media that have been designed by students while attending Optics lectures. Making learning media is intended to train student teacher candidates in preparing for physics learning to the fullest by using aids in the form of learning media that can be made using inexpensive materials.

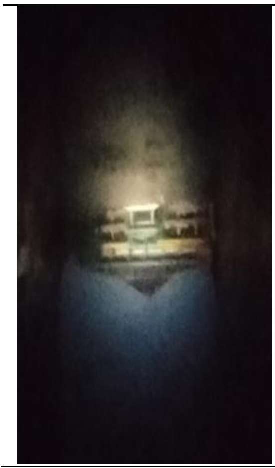
a. Pinhole Camera

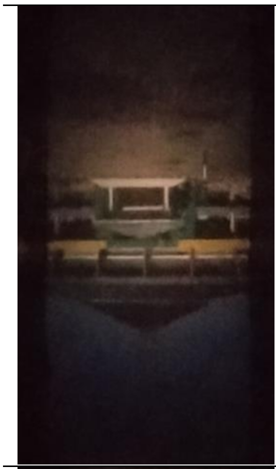
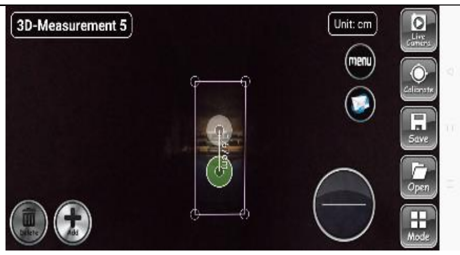
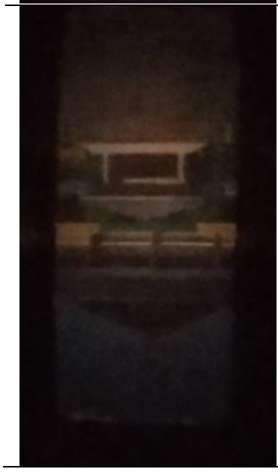
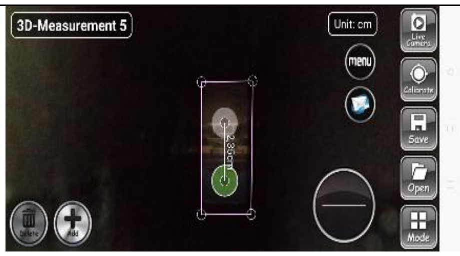
The pinhole camera used as a learning media for light propagation in a straight line. This pinhole camera made of cardboard which is then coated with used wood veneer, and taped on the corner surface to make it look presentable.

Figure 1. Pinhole camera

The incoming light into pinhole camera will produce shadows of an objects in front of the pinhole. The shadow of the object that is seen is then analyzed using the measure pro application to find out how high the shadow is. Experiments using pinhole camera were carried out using a variable distance between the screen and the pinhole (manipulated variable), while the distance between the pinhole camera and objects was fixed (controlled variable). The object used in this experiment is the GSG Lampung University, which based on the calculation of the measure pro application has a height of 23.7 m, while the distance of the GSG Lampung University with a pinhole camera is 53.3 m. The following is data from observations using a pinhole camera.

Tabel 1. Pinhole Camera Observation Data

Shadow Results	Screen Distance	Shadow Height Analysis	Shadow Height
	5,0 cm		0,76 cm

	10 cm		1,67 cm
	15 cm		2,35 cm

The magnification (respons variable) ratio of objects (M) on the pinhole can be mathematically obtained by comparing the image height (h') with the actual object height (h). However, to obtain the magnification ratio of the object, we can look for it without having to know the image height first, namely by utilizing the ratio between the image distance from the pinhole (d') with the pinhole distance to the object (d).

$$M = \frac{h'}{h} = \frac{d'}{d}$$

We also perform calculations manually using these equations in order to compare the results of application calculations with the results of manual calculations. The results of manual calculations using these equations turned out to have different values from the application calculations which can be seen in the following table.

Table 2. Comparison of the calculation results

Screen to Pinhole Distance	Application Calculation	Manual Calculation
5.0 cm	0.76 cm	2.22 cm
10 cm	1.67 cm	4.45 cm
15cm	2.35 cm	6.67 cm

The difference in the calculation results can be caused by several factors. We predict the cause of the difference in the application measurement results about the height of the building object and the distance between the pinhole camera to the building. There are many things that can affect the measurement results such as the quality of the cellphone camera used, the position of the cellphone is not perpendicular when measuring, and light or weather conditions that can interfere with taking pictures. However, it should be underlined that learning media such as simple teaching aids do not always have to have accurate scale results. This study focuses more on results that are in accordance with the theory, where a change in the independent variable must produce an appropriate change in the response variable.

The measurement results show a suitable relationship between changes in the image distance from the pinhole (d') with image height (h') formed on the pinhole camera. The relationship between the two variables shows a directly proportional relationship, so it can be written as.

$$d' \sim h'$$

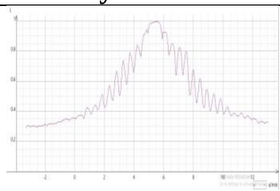
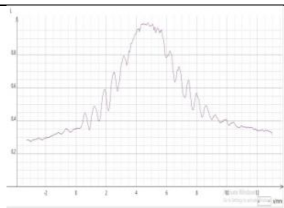
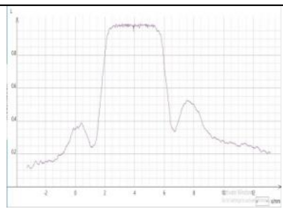
b. Simple Light Diffraction Props

This simple light diffraction teaching aid used to help explain the characteristics of light diffraction. This apparatus made by a recyled cardboard, recyled pens, and recyled wooden boards and divided into three parts, namely the lattice and laser section, the phonecell holder, and the capture screen.

Figure 2. The simple light diffraction teaching aid

This visual aid utilizes a laser beam as a light source, and a phonecell camera is used to take pictures of the light diffraction pattern. The light diffraction pattern is then analyzed using a tracker application to determine the intensity and width of the center of the light diffraction pattern. In this experiment, the props used independent variables in the form of the width of the diffraction grating ($\boldsymbol{w}$) recyled, the dependent variable on the distance from the grating to the screen ($\boldsymbol{x}$) and the response variable, namely the width of the center of light ($\boldsymbol{y}$) the diffraction pattern formed. The results of an experiment using this simple light diffraction aid could see below.

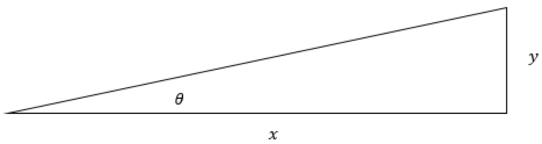
Table 3. Experimental Results of Simple Light Diffraction Props

Grid Size	Grid to Screen Distance	Diffraction Pattern	Diffraction Pattern Analysis Results
0,5 mm	320,0 cm		
0,3 mm	320,0 cm		
0,1 mm	320,0 cm		

The width of the center of light in the diffraction pattern can be found by assuming the distance between the screen and the lattice is very large, so that the maximum angle of center of light given by this equation below.

$$sin\,\theta \approx \theta$$
$$w\,sin\,\theta = \pm\,\lambda$$
$$\theta = \pm\,\frac{\lambda}{w}$$
$$\theta = \pm\,2\frac{\lambda}{w}$$

This equation helps students to determine how wide the bright center of the diffraction pattern is using the rule of tan θ. Because the distance between the lattice and the screen is assumed to be extremely far, the value of tan is $\theta \approx \theta$ also, so that the width of the center of the diffraction pattern can be found by using the following equation.



$$tan\,\theta = \frac{y}{x}$$
$$\theta = \frac{y}{x}$$
$$\frac{2\lambda}{w} = \frac{y}{x}$$

$$y = x\frac{2\lambda}{w}$$

The experimental results using this simple light diffraction prop visually show that there is an appropriate relationship between changes in the size of the diffraction grating and changes in the width of the central light. Based on the above equation and the experimental results, the relationship between the size of the diffraction grating and the width of the central light can be written as:

$$w \sim \frac{1}{y}$$

▪ CONCLUSION

This study proves that physics experiments can be carried out by utilizing learning media in the form of low cost material teaching aids.This aid can train science process skills that can be raised and seen directly include the skills of students in measuring, determining variables, conducting experiments, making tables and graphs, determining relationships between variables, manipulating tools and materials, interpreting data, and drawing conclusions. The teaching aids that have been produced by students have simple specification can be operated through online and offline, these teaching aids are sufficient to be used during blended learning. The software used to describe the diffraction pattern is tracker applcation that can be accessed via online by laptop or computer.

Teaching aids should be designed as well as possible in advance, this will minimize the factors that can interfere with data collection. The use of phonecell cameras and additional applications is also very influential with the experimental results, especially on optical materials that use light in the object of research. Camera resolution, shooting position, and inappropriate application usage will greatly affect the analysis results, so the process of taking pictures and analysis should be carried out carefully and precisely.

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