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Development of Practicum Tools for Learning the Concept of Light Interference Assisted by the ESP-32 Camera Sensor to Practice Science Process Skills

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Abstract
This research aims to develop a practicum tools with assisted by the ESP-32 camera sensor which can be used in learning the matter of light interference at school, as well as to train science process skills. This research uses a Design and Development Research (DDR) approach, which is divided into three stages, that are analysis, design and development, and evaluation. Before this practicum tool is used in the field to help the learning process, this practicum tool is tested for feasibility first. The feasibility test of the practicum tools for the matter of light interference was carried out using a validity test and practicality test. The results of the practicum tools validity test obtained a percentage of 86% with a very valid category and the indicator for the usefulness of practicum tools in science process skills was 81%. The results of the practicality test obtained a percentage of 84% in the very practicality category. Based on these two feasibility tests, it can be concluded that the practicum tool is suitable for use in learning the matter of light interference at school, and can train students' science process skills. Indicators of scientific process skills that are trained are observing, communicating, controlling variables, hypothesizing, experimentation, and interpreting data.

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1. Introduction

21st century learning is designed for students to be able to follow the flow of technological developments. Students are required to have four aspects of learning skills (4C), that are critical thinking, communication, collaboration and creativity. In addition, 21st century learning provides students with the opportunity to be active in the learning process. This shows that learning in the 21st century is shifting from teacher-centered learning to student-centered learning [1].

One form of learning that is student-centered is learning that focuses on science process skills. Science process skills are very important for students to be able to understand and carry out scientific processes to discover and develop concepts [2]. Science process skills can be used to solve physics problems experienced by students in daily life [3]. Science process skills in science education literacy refer to several actions such as observation, communication, classification, inference, and measuring [4].

Physics learning is the matter that is closely related to phenomena or events in daily life. By studying these phenomena you can develop students' scientific thinking skills. The phenomenon interference of light is one of the core components of physical optics because it provides the first experimental evidence regarding the wave nature of light [5]. Research conducted by Lutfia & Putra [6] states that students who experience misconceptions are because students still have difficulty explaining the concept of interference events. Misunderstanding of the indicators explains the condition of light interference because some students still experience problems in carrying out the learning process and reading existing textbooks.

The results of the researcher's preliminary study at different high schools, that are SMAN 1 Sumberejo, SMAN 1 Kotaagung, SMAN 1 Abung Semuli, and SMAN 1 Pringsewu, found that 44.4% of students did not understand the matter of light interference because the matter was difficult and understanding of the concept was still lacking. Students mentioned their difficulties in understanding light interference material due to the lack of explanation given by the teacher, lack of basic understanding of light interference material, and also problems with the online learning system at that time. Meanwhile, the practice of science process skills itself has not run optimally because the learning process at the school is still carried out online due to the Covid-19 pandemic. As many as 66.7% of students have never done practikum work on the concept of light interference. Students receive an explanation of the material from the teacher through lectures, discussions, questions and answers, and practice questions. As many as 76.9% of students thought that they would be able to understand the concept of light interference matter if they carried out practicum activities and not just learning in class by listening to the teacher explain the matter. Students will be more interested if the teacher explains the material using tool-based media (92.6% of respondents) and learning videos (40.7% of respondents).

As a result of distributing questionnaires to teachers in different high schools, it was found that 60% of respondents stated that the matter of light interference was difficult to teach because students still lacked basic concepts about light. There were 60% of respondents who stated that practicum activities were not carried out in the learning process due to the unavailability of tools. When delivering material, teachers usually use additional media such as PowerPoint and learning videos. There are also teachers who use Phet Simulation to train students' skills. Students' science process skills have not been trained optimally due to lack of experience and the science process is provided directly. Teachers believe that these skills can be trained if practicum activities are carried out in the learning process and practicum tools are available at school. Apart from that, the use of other supporting media such as application-based and video-based learning media will make students interested in the learning process because learning becomes more creative and less monotonous.

Advances in science and technology have produced various electronic devices that can help in developing tools creatively and innovatively according to learning objectives. With various existing electronic devices, the resulting design of practicum tools is more effective, efficient, and has better accuracy of measurement results and visualization. Supported by rapid technological advances in the current digital era, conventional practicum tools can be digitized with the help of microcontroller developments [7].

This practical tool is a development of the previous tool. Previous light interference practical tools for displaying interference patterns manually did not display interference patterns visually which were displayed directly on the laptop screen in graphic form. A similar practical tool has been developed by Wijaya [4], but this practical tool is for analyzing diffraction patterns and uses diffraction slits as gratings. In his research, Wijaya also used an ESP-32 camera module but used an Arduino UNO as a power supplier for the camera module.

The practical tool developed by researchers uses grids from several different types of cellphone LCDs and does not use Arduino as a power supplier for the camera module but instead uses a special ESP-32 downloader, namely the CH340 development board which is more practical and easy to use. Research conducted by Ong et al., [8], low science process skills can be caused by learning methods that only focus on open books, boring memorization, passive learning, and so on. Then according to Ongowo & Indoshi [9], integrated science process skills require a series of consistent learning and some direct practice. Thus, practicum tools are considered effective and very suitable for teachers to use in explaining abstract material and can train students' science process skills [4].

Based on the description above, the development of practicum tools for learning the concept of light interference can support physics learning to improve students' science process skills. The unavailability of practicum tools in explaining light interference material became the basic for researchers in conducting research to developing of practicum tools for learning the concept of light interference assisted by the ESP-32 camera sensor to practice science process skills.

2. Methods

This research uses a Design and Development Research (DDR) approach, a type of product development research adapted from Richey and Client [10]. Where the DDR approach consists of three stages, that are analysis, design and development, and evaluation. The analysis stage was carried out by distributing questionnaires to teachers and students from different high schools regarding learning about light interference in schools.

The design and development stage begins with selecting the materials needed to manufacture light interference practikum tools products. Researchers use materials of good quality, easy to find in the surrounding environment, and at affordable prices. The stages of making a light interference practicum tool are making the body frame of the tool made of wood in a rectangular shape measuring 200 cm and ± 10 cm thick and making the components that must be in the practicum tool. In the development stage, researchers carried out programming to develop the ESP-32 camera sensor and tracker application so that it could be used and operated in tool experiments. Researchers used a special downloader built into the ESP-32, namely the CH340 development board, to assist in the programming and processing of the data obtained. The results of the experimental data obtained were then analyzed using a tracker application that was installed on the laptop by connecting it using a USB cable. The results of data analysis using this tracker are expected to help students understand the concept of light interference with visualization. The following are the results of the design and development stages carried out by researchers, presented in Figure 1.

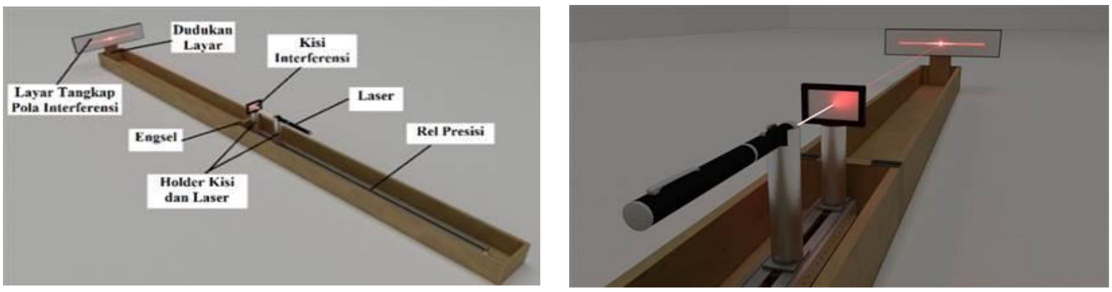
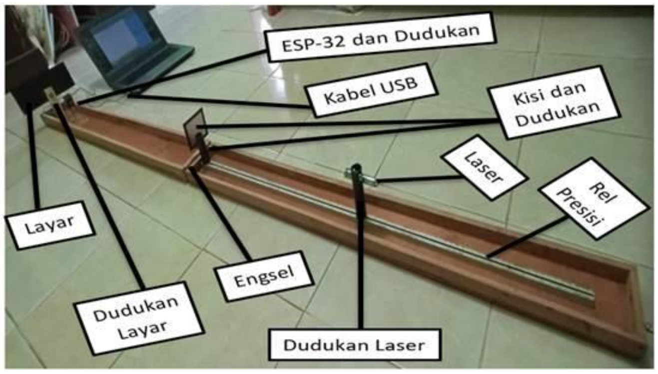


Figure 1. Design of Teaching Aid and Process of Light Passing Through a Grating



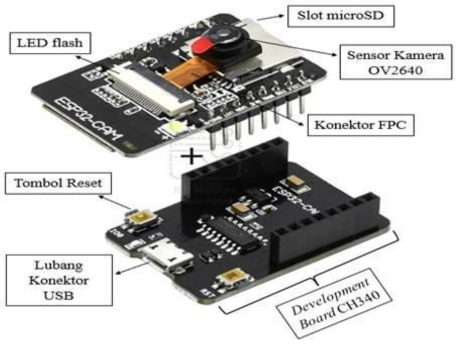


Figure 2. Results of the Development of a Simple Light Interference Teaching Aid

Before carrying out the validity test and practicality test, the researcher carried out an independent product trial (pre-validity test). The purpose of conducting this pre-validity test is to test the validity empirically, whether the product of the light interference practikum tool being developed is in accordance with existing theoretical studies. The evaluation stage of the research is carried out to determine developments in the research process and to determine the achievements of the research process that has been implemented. At the evaluation stage, researchers make improvements at each stage of the research based on suggestions and input from validators and based on the results of pre-validity tests.

The research instruments used were a needs analysis questionnaire, a validity test questionnaire, and a practicality test questionnaire. The needs analysis questionnaire is used to find out facts about the learning media used by teachers and the expected use of learning media by teachers and students when learning about light interference at school. The validity test questionnaire aims to determine the level of validity of the practicum tool product being developed so that it can be used as a learning medium for interference of light matter. The practicality test questionnaire was used to find out respondents' responses regarding the practicality of the light interference practicum tool that has been developed.

Data analysis techniques are very important in the scientific method, because by analyzing data we can find out whether the data can be given meaning or meaning that is useful in solving research problems [11]. The data analysis technique used in this research is quantitative data techniques. Where, assessment data was obtained from the results of validator questionnaire tests and questionnaire responses from practicum tool users which were analyzed descriptively qualitatively. The results of the assessment of all aspects will be measured using a Likert scale. The Likert scale is a measurement scale in the form of positive or negative statements about an object [12].

3. Results and Discussion

The results of the assessment of all aspects will be measured The results of this development research are (1) the product of a light interference practicum tool assisted by an ESP-32 camera sensor to practice science process skills, (2) an assessment of the validity of a simple light interference practicum tool by material, media and design experts, (3) practicality questionnaire data simple light interference practikum tool by respondents. The first step used in conducting this research was analyzing needs by identifying problems, hopes and solutions that can be applied in the field regarding learning light interference in schools. After these steps have been carried out, researchers can start designing and developing simple light interference practicum tools.

This practicum tool was developed and researched using the DDR development model adapted from the Richey and Klein approach [10] consisting of three stages,that are analysis, design and development, and evaluation. After carrying out these stages, a practicum tool was produced in the form of a simple light interference practikum tool assisted by an ESP-32 camera sensor to practice science process skills. The following are the results of the development of a simple light interference practicum tool assisted by the ESP-32 camera sensor.

In this research, before the expert validation test was carried out, the researcher carried out a pre-validity test independently. The purpose of conducting this validity pre-test is to empirically test the validity of the experimental results in accordance with existing theoretical studies. Practicum tool experiments were carried out using response variables and dependent variables in the form of the distance of the grating to the screen and the type of grating used. The analysis process is carried out using a tracker application. Analysis using this tracker application obtains data in the form of graphs of interference patterns, light intensity values, and width between light patterns. The following are the results of product trials carried out by researchers, presented in the form of Figure 3, Figure 4, Figure 5, and Figure 6.

S	0,25m	0,50m	0,75m
Interference Patterns			
Chart			
Light Intensity and Width	188,5 luma 10,1	188,2 luma 11,6	181,1 luma 13,4

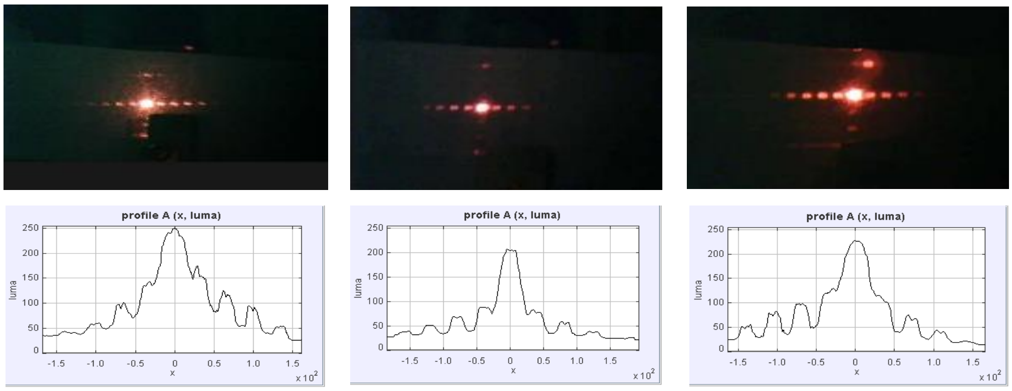


Figure 3. Variable Distance of Grating to Screen on LCD 1

S	0,25m	0,50m	0,75m
Interference Patterns			
Chart			
Light Intensity and Width	249,6 luma 17,9	235,5 luma 18,0	226,3 luma 19,4

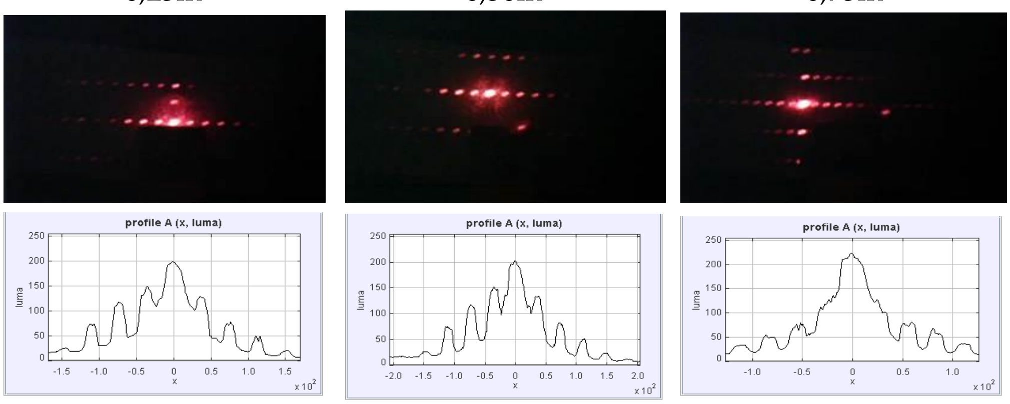


Figure 4. Variable Distance of Grating to Screen on LCD 2

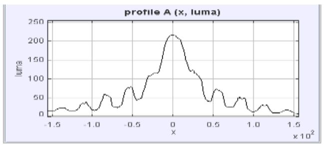
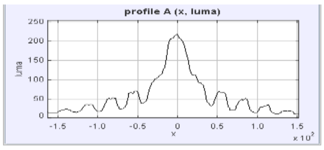
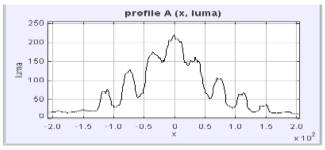
S	0,25m	0,50m	0,75m
Interference Patterns			
Chart			
Light Intensity and Width	254,0 luma 16,3	218,1 luma 16,5	211,4 luma 20,1

Figure 5. Variable Distance of Grating to Screen on LCD 3

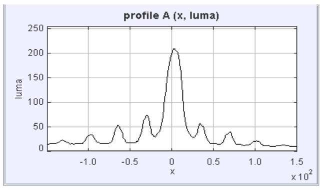
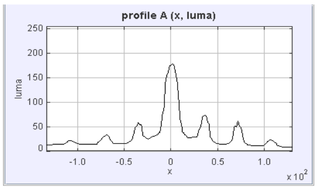
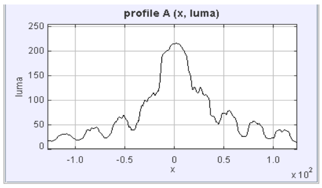
S	LCD 1	LCD 2	LCD 3
Interference Patterns			
Chart			
Light Intensity and Width	177,3 luma 23,9	209,7 luma 21,1	215 luma 17,3

Figure 6. Variation of Grating Variable

The validation test was carried out by three expert validators who provided assessments based on assessment aspects including: material aspects, aspects of usefulness in science process skills, illustration aspects, and aspects of the appearance and quality of practicum tools. Expert validation results show an overall average of 86% for very valid criteria. The following are the results of expert validation regarding a simple light interference practicum tool developed by researchers, presented in the form of Table 1.

Table 1. Expert Validation Test Results

No.	Assessed Aspects	Percentage	Qualitative Statement
1.	Materials	91%	Very High Validity
2.	Usefulness of Science Process Skills	81%	Very High Validity
3.	Illustration	91%	Very High Validity
4.	Quality and Appearance of Practicum Tool	83%	Very High Validity
	Final Average	**84%**	**Very High Validity**

The practicality test was carried out by six Physics education students at the University of Lampung who had taken and passed the optics course to provide an assessment based on four aspects, including: usefulness aspect, ease of use aspect, ease of learning aspect, and satisfaction. The practicality test results show an overall average of 84% on very high practicality criteria. The following are the results of practicality tests related to the light interference practice tool developed by researchers, presented in Table 2.

Table 2. Practicality Test Results

No.	Assessed Aspects	Percentage	Qualitative Statement
1.	Usefulness	82%	Very High practicality
2.	Ease of Use	88%	Very High Practicality
3.	Ease of Learning	82%	Very High Practicality
4.	Satisfaction	83%	Very High Practicality
	Final Average	**84%**	**Very High Practicality**

A simple light interference practicum tools assisted by the ESP-32 camera sensor is designed to show the effect of the distance of the grating to the screen and the type of grating used on the light interference pattern formed. The interference pattern formed on the capture screen is then recorded by the ESP-32 camera sensor and then analyzed using a tracker application. The ESP-32 camera sensor was chosen because it is one type of camera sensor that is often used in devices that utilize camera features, is widely spread on the market, and the price is relatively affordable. In developing the ESP-32 camera sensor, it was assisted by a development board, namely the CH340 development board, which is a special downloader built into the ESP-32 to help send data to the laptop/computer. This practicum tools is made from materials that are easily obtained, for example recycled materials or materials at affordable prices. Practicum tools are designed to assist teachers in learning simple light interference concepts to be able to train students' science process skills.

Before carrying out a validity test and practicality test on the product of a simple light interference practikum tools assisted by an ESP-32 camera sensor to practice science process skills, the researcher carried out a pre-validity test independently. When conducting independent product trials, this is done using response variables and dependent variables in the form of the distance of the grating to the screen and the type of grating used. The results of independent product testing are that the distance of the grating to the screen is directly proportional to the width of the central light and the next light, and inversely proportional to the intensity of the central light. Mathematically it can be written as follows.

$$L \sim P \qquad \text{and} \qquad L \sim \frac{1}{I}$$

with: L = distance of LCD to screen (m), P = the width between the center light and the next light (m)
I = Intensity at the central light (luma)

The results obtained were that the type of grating used would be directly proportional to the intensity of the central light, and inversely proportional to the width between the central light and the following lights.

$$W \sim I \quad \text{and} \quad W \sim \frac{1}{P}$$

with: W = grating type, P = the width between the center light and the next light (m), I = Intensity at the central light (luma)

The experimental results are in accordance with theoretical studies that light interference is a combination of two or more light sources to produce a brighter state (maximum interference) and a dark state (minimum interference). The condition for light interference to occur is that the light must be coherent, namely the condition of two or more light sources that have a fixed frequency, amplitude and phase difference. The pattern formed is in accordance with the theory that constructive interference will occur, marked by a maximum bright line and destructive interference marked by a maximum dark line. This is due to the uneven distribution of light energy so that there are dark areas and light areas [13]. If the gap passed through is wider than the wavelength, then the angle θ will be small, which causes the width of the central light to also become smaller. This is because the light beam passes through the gap without any obstruction. On the other hand, if the slit width is only a few times greater than the wavelength, for example only 5 times greater, the spread of the light beam will be greater, as indicated by the greater width of the central light [14].

The procedure for using this light interference practicum toosl is divided into two stages. The first stage is the procedure for assembling practikum tools and the second stage is the procedure for taking and analyzing images. Through this activity, students will carry out hands-on experiments and minds-on experiments as well as learning about light interference. Hands-on experiment activities are characterized by students' physical (psychomotor) activities using practikum tools that have been developed, while minds-on experiments are not only focused on cognitive activities, but also include students psychomotor activities. This is because even though students carry out physical activities in learning such as conducting experiments, of course there are also cognitive activities in them. As long as there are experimental activities in learning, students will automatically also carry out psychic activities, in this case mind-on activities [15].

This simple light interference practikum tools was developed so that it can be used to analyze light interference patterns, and can help teachers train students science process skills. The indicators of science process skills used in this research are observing, communicating, controlling variables, hypothesizing, experimentation, and data interpreting which were adapted from Chiappetta and Koballa [16].

In the procedure for using this tool, students will indirectly carry out indicators of science process skills, namely controlling variables. This is indicated by students choosing the size of the grid used in the experiment and determining the distance between the grid and the capture screen. Apart from that, before carrying out experimental activities, the teacher should first provide a stimulus to the students. The stimulus can be in the form of photos, videos or explanations related to the material being discussed. At this stage, students carry out observing activities by utilizing their senses to observe, note the nature or situation of the object to be observed. In the experimental process, this practikum tool was carried out in minimal room light conditions so that the interference pattern appeared brighter on the screen, and minimized the presence of outside light which was also recorded by the camera module. It is hoped that this conditioning will enable the experimental data to have better accuracy. At this stage students can provide their hypothesis (hypothesizing) about how the distance of the grid to the screen is affected, as well as the effect of the type of grid on the interference pattern. Apart from that, students will test their hypotheses through experimental activities.

The experimental data presented in the form of tables and graphs above indicates that students can carry out other indicators of science process skills with the help of this practikum tool, namely communicating, then continue with the final indicator, namely data interpreting, such as interpreting data and drawing conclusions.

Conclusion

Based on the results of research and development of practicum tools for learning the concept of light interference assisted by the ESP-32 camera sensor, it can be concluded that the light interference practicum tools were declared valid by experts through four assessment aspects, namely material, usefulness in science process skills, illustrations, and quality and the display of practikum tools with a percentage of 86% is in the very good category. The practicum tools were then declared practikum by respondents through four assessment aspects, that are usefulness, ease of use, ease of learning, and satisfaction with a percentage of 84% in the very good category. Based on the test results, a simple light interference practicum tools assisted by the ESP-32 camera sensor was declared very feasible and practicality to use as a physics learning media in schools, especially light interference material and suitable for training students' science process skills.

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