JIPF (JURNAL ILMU PENDIDIKAN FISIKA)
p-ISSN: 2477-5959 | e-ISSN: 2477-8451 *Vol. 7 No. 3, September 2022, Page 306-315*

Development of Simple Light Diffraction Props Assisted by Tracker Application with Camera Module and Arduino UNO

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Received: December 27th, 2021. Revised: June 17th, 2022. Accepted: August 1st, 2022

Keywords :
Diffraction of Light; Science Process Skills; Tracker Application

ABSTRACT
This study aims to develop simple light diffraction teaching aids that can be used in learning light diffraction material in schools, as well as to train students' science process skills. This study uses the type of research Design Development and Research (DDR) which is divided into four stages of research, namely analysis, design, development, and evaluation. Before being used in the field, these props were first tested for feasibility. The feasibility test of this light diffraction teaching aid was carried out by conducting a validity test, practicality test, and instrument effectiveness test. In the test results of the validity of teaching aids obtained a percentage of 93% with a very valid category. The results of the practicality test obtained a percentage value of 89% with a very practical category. The results of the test of the effectiveness of teaching aids are represented by the student response test, and the teacher's perception test. In the student response test, a percentage of 86% was obtained in the very effective category, while the teacher perception test obtained a percentage of 84% in the very effective category. Based on the three feasibility tests that have been carried out, it can be concluded that this teaching aid is very suitable to be used in learning diffraction material in schools, and can train students' science process skills.

INTRODUCTION

Students learn science well through direct experience using the inquiry method and process [1]. The inquiry method is a learner-centered learning method, focusing on how that knowledge is obtained. The inquiry method involves students as active thinkers, seekers, and information processors [2] [3] identified scientific knowledge into two domains, namely, content knowledge and process skills. Content knowledge includes theories, models, facts, and principles, while process skills include procedural knowledge used in science such as observations, hypotheses, and measurements. Learning in the 21st century has also implemented a learning process using a scientific approach which is marked by a shift from educator-centered learning to student-centered learning [4]. One of the learner-centered learning is learning that focuses on science process skills (SPS). Science process skills are skills to carry out activities related to practice, where students are required to experience for themselves, discover, and connect experimental results with existing theories [5].

Science process skills are divided into two broad lines, namely basic science process skills, and integrated science process skills. Basic science process skills include observing, comparing, classifying, defining, measuring, formulating models, compiling tables and graphs, taking notes and interpreting, and inferring [6]. Integrated science process skills are a more complex process. Integrated science process skills combine two or more basic science process skills in research. Examples of integrated science process skills are controlling variables, formulating hypotheses, experimenting, and interpreting data [7]. Science process skills are very suitable to be trained with hands-on experiments. This is in accordance with the opinion of Ates & Eryilmaz [8], that hands-on experiments can help students to encourage their creativity in solving problems, foster independence, and improve science attitudes and science process skills. Klopfer claims that hands-on experiments allow students to obtain the results of observations and measurements [9].

The difficulty of students in understanding physical optics topics such as light diffraction is caused by the fact that physical optics is a material that involves non-intuitive concepts [10]. Light diffraction is one of the abstract physics subject matter, so it takes a medium or a tool to explain by conducting experiments [11]. Research conducted by McDermott [12] shows that many students who have studied light diffraction have conceptual and reasoning difficulties to explain light diffraction. One way that has the potential to reduce the abstraction of light diffraction material is visualization, for example when conducting experiments in learning [13].

The Integrated Instrument Box in the form of complete factory-made teaching aids, non-instrument box teaching aids, and physics teaching aids from the Ministry of Education and Culture has not been evenly received by schools [11]. Whereas learning media is used as a teacher's tool in delivering subject matter to students. Utilization of appropriate learning media in accordance with the content of the material and learning methods will make learning take place effectively, efficiently, and interestingly [14]. One of the efforts to fulfill this is by developing an appropriate learning media to increase the enthusiasm and learning outcomes of students [15]. Learning media must function to improve the quality of teaching and learning [16]. The role of media in the learning process is important because it will make the learning process more varied and less boring [17]. This is reinforced by the opinion from Wati et al. [18] which states that learning media is a tool that serves to explain the subject matter as a whole which is difficult to explain if only verbally.

Many science experiments or data collection can be done with the help of simple materials that are inexpensive and easy to find [8]. Several criteria that must be considered in preparing simple teaching aids are; a) the materials used are widely available, easy to obtain, and relatively inexpensive, b) the preparation is simple (not complicated), c) its use does not require a long time, d) its use should create feelings such as enthusiasm and surprise in students [19]. Data measurement techniques have also been developed rapidly in recent years. This development was marked by the transition from the analog measurement era to the digital measurement era [20]. This transition is based on human knowledge about computer performance which currently can not only process text but can also be used to process data or images [21]. Technological advances in the field of measurement are then used to overcome students' learning difficulties in understanding light diffraction. This study aims to develop a simple light diffraction tool that can assist in digitally visualizing and measuring light diffraction patterns.

METHOD

This study uses Design and Development Research (DDR), a category of product development research adapted from Richey & Client [22]. This research procedure consists of 4 stages, namely, analysis, design, development, and evaluation. The analysis stage was carried out by observing through the distribution of questionnaires to teachers and students related to light diffraction learning at school. The design of light diffraction props is divided into two parts, namely designing electronic circuits on the props, and designing the body of the props. The development stage is carried out by making teaching aids and conducting a validity test, then proceed to the practicality test stage, student response test, and teacher perception test. The validity instruments used include material aspects, the usefulness of science process skills, illustrations, the quality and appearance of teaching aids, and the usefulness of teaching aids in learning. The evaluation stage in this study consisted of two kinds, namely summative and formative evaluation.

The development of this teaching aid also utilizes simple materials that are easy to find and inexpensive. Some of these materials are used cardboard, used pens, clothes hanger wire, straws and sim-card pieces. The bodies of these props are all made of HVS/photocopy paper cardboard, because the cardboard has a denser texture with a thinner size. The pen is used as a support for the capture screen and laser, while the clothes hanger wire is used as a support for the camera module which is attached to a holder that has been given a straw. Two pieces of sim-card are squeezed so as to form a gap. The size of the gap used as a diffraction grating in this study were 0.3 mm, 0.4 mm, and 0.5 mm. The following is the design of the props developed.

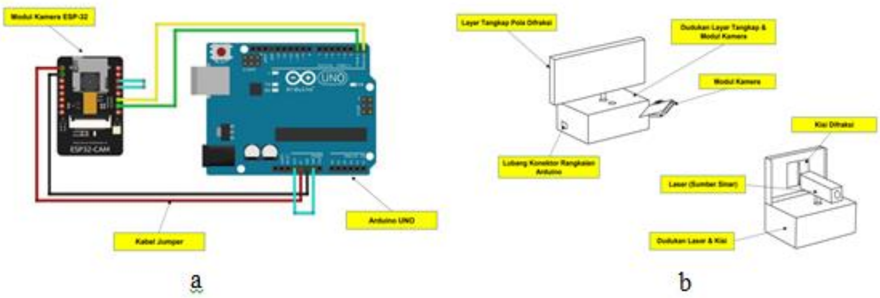


Fig 1. *a) Electronic Circuit b) Body Props*

The experiment in this study assumes that the diffraction that occurs is Fraunhofer diffraction using a single slit. This study also does not use two converging lenses as a condition for ideal Fraunhofer diffraction, and the incident light source is considered as a parallel light source. The experiment was conducted using the response variable and the dependent variable, namely the distance from the grating to the screen, and the width of the diffraction grating.

RESULTS AND DISCUSSIONS

Results

1. Product

The product produced in this development research is in the form of a simple light diffraction teaching aid with a tracker application as shown in the following figure.

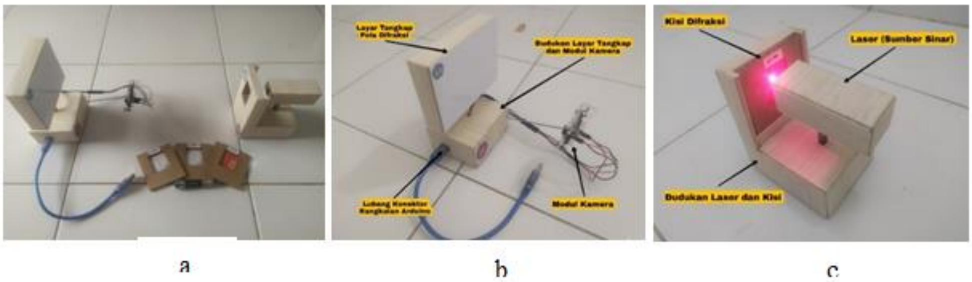


Fig 2. *a) Props Products, b) Part 1 Props, c) Part 2 Props*

This teaching aid consists of two main parts which can be seen in the following two Figures. The first part consists of the capture screen holder and camera module, the diffraction pattern capture screen, the ESP-32 camera module, and the Arduino connector hole. The second part consists of a laser mount and a grating, a diffraction grating, and a laser used as a light source.

2. Validity Test

The validity test was carried out by three competent experts in their fields. The questions posed to the validators included how well these teaching aids can help teachers in presenting learning materials, how well these teaching aids can help students make qualitative measurements, and how well these teaching aids can help students visualize light diffraction patterns. The following are the results of the validity test data analysis that has been carried out.

Table 1. Validity Test Results

No.	**Rated aspect**	**Validator Average Score**	**Qualitative Statement**
1	Material	97%	Very High Validity
2	Benefit on Science Process Skills	89%	Very High Validity
3	Illustration	97%	Very High Validity
4	Quality and Display of Props	88%	Very High Validity
5	Benefits of Learning Tools	95%	Very High Validity
	Final Average	**93%**	**Very High Validity**

3. Experiment Data

Experimental data was obtained by conducting experiments in minimal room light conditions so that the diffraction pattern appears brighter on the screen. The experiment was carried out in two series of experiments. The first series of experiments used the dependent variable, namely the lattice size of 0.3 mm with the independent variable being the separation distance between the diffraction grating and the screen of 0.5 m, 1 m, and 1.5 m. The second series of experiments used the dependent variable, namely the separation distance between the diffraction grating to the screen of 1.5 m with the independent variable being the size of the diffraction grating of 0.3 mm, 0.4 mm, and 0.5 mm.

The diffraction pattern that appears on the web-server is then analyzed using a tracker application to obtain a graph of the diffraction pattern, intensity value, and x-value at each point of the diffraction pattern. The intensity value in this case is represented by the y-axis, while the x-value is represented by the x-axis which is used to determine the width of the light pattern and the dark pattern in the light diffraction pattern formed. However, in this study only focused on the intensity and width of the center light of the diffraction pattern. The following is the experimental data that has been carried out.

Table 2. Variable Grid-to-Screen Distance

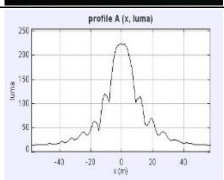
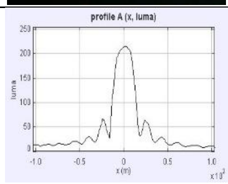
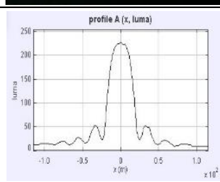
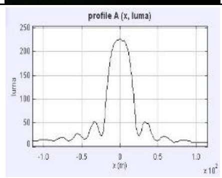
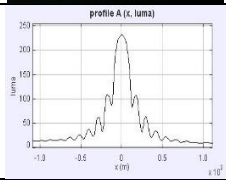
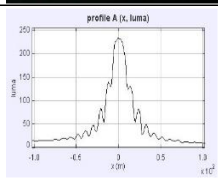
S	**0.5m**	**1 m**	**1.5m**
Diffraction Pattern			
Chart			
Center Light Intensity and Width	223.8 luma 17.0	213.8 luma 34.99	206.9 luma 48.99

Table 3. Variable Diffraction Grating Width

w	0.3mm	0.4 mm	0.5mm
Diffraction Pattern			
Chart			
Center Light Intensity and Width	206, 9 luma 48.99	231.8 luma 24.99	234.0 luma 20.0

4. *Practicality Test*

The practicality test was carried out using respondents from six students who had taken optical courses, the questions asked to the respondents included whether this teaching aid could make it easier to visualize the diffraction pattern of light, whether this teaching aid was easy to use, and whether this teaching aid was easy to learn how to use. The following are the results of the practicality test data analysis that has been carried out.

Table 4. Practicality Test Results

No.	Rated aspect	Average Score	Qualitative Statement
1	Usefulness	92%	Very good
2	Ease of Use	85%	Very good
3	Ease of Learning	86%	Very good
4	Satisfaction	92%	Very good
Final Average		**89%**	**Very good**

5. *Student Response Test*

The following are the results of the data analysis of the student response tests that have been carried out.

Table 5. Student Response Test Results

Question to-	Average Score	Qualitative Statement
1	84%	Very good
2	82%	Very good
3	87%	Very good
4	85%	Very good
5	82%	Very good
6	85%	Very good
7	84%	Very good
8	92%	Very good
9	89%	Very good
10	87%	Very good
11	82%	Very good
12	93%	Very good
13	90%	Very good
14	85%	Very good
15	87%	Very good
Final Average	**86%**	**Very good**

DOI: 10.26737/jipf.v7i3.2989

6. Teacher's Perception Test

The teacher perception test was conducted with five teachers from different schools as respondents. The questions asked in this teacher perception test include whether the use of this teaching aid can help students in designing light diffraction experiments, whether the use of this teaching aid can help students in analyzing the experimental results, and whether these teaching aids can help students in presenting experimental data with graphs and tables. The following is the result of the data analysis of the teacher's perception test that has been carried out.

Table 6. Teacher's Perception Test Results

No.	Rated aspect	Teacher's Average Score	Qualitative Statement
1	Observing and Defining the Problem	84%	Very good
2	Formulating Problems and Making Hypotheses	80%	Good
3	Determining Variables and Performing Experiments	84%	Very good
4	Collecting and Presenting Data	85%	Very good
5	Interpreting Data	87%	Very good
	Final Average	**84%**	**Very good**

Discussion

The development of teaching aids is carried out in accordance with the designs or designs that have been made in the previous stage. At this stage, a product is produced in the form of a simple light diffraction teaching aid with the aid of a tracker application which can be seen in Figure 1. At this stage an experiment of teaching aids was also carried out which was then continued with validation tests, practicality tests and tests of the effectiveness of the teaching aids.

1. Props Experiment Data

If we look at the three experimental data on the effect of the lattice-to-screen distance in Table 3, it can be concluded that the lattice-to-screen distance is directly proportional to the width of the center light, and inversely proportional to the intensity of the central light. Mathematically it can be written as follows.

$$\boldsymbol{s \sim l} \qquad \boldsymbol{s \sim \frac{1}{I}}$$

with:

s : Grid-to-screen distance (m)

I : Intensity in central light (luma)

l : Center light width

Based on the three experimental data on the effect of lattice width in Table 4, it can be concluded that the size of the lattice width used will be directly proportional to the intensity of the central light, and inversely proportional to the width of the central light.

$$\boldsymbol{w \sim I} \qquad \boldsymbol{w \sim \frac{1}{l}}$$

with:

w : Grid size (mm)

I : Intensity in central light (luma)

l : Center light width

The test results are in accordance with the theory that if the slit through which the light beam passes has a size wider than the wavelength, then the angle value □will be small, this causes the width of the center of the light diffraction pattern to also be smaller. This is caused by the light beam passing through the slit almost no diffraction effect (the ray passes through the slit without any obstacles). On the other hand, if the slit width is only a few times larger than the wavelength (say only 5 times larger), then the spread of the light beam due to diffraction will be wider, which is indicated by the greater width of the center light (Giordano, 2010). It is also appropriate that the diffraction pattern consists of a central bright band, the size of which can be much wider than the width of the slit through which this central light band is bounded by a dark color and another light band with decreasing intensity. About 85% of the power in the transmitted beam will be in the central bright band. This central bright band has a width that is inversely proportional to the width of the slit (Young, and Freedman, 2012).

2. Validity test

The validity test was conducted to determine the feasibility of the product before it was implemented in the learning process. The validity test was carried out by 3 experts using a questionnaire consisting of 6 assessment aspects, namely the material aspect, the usefulness of science process skills, illustrations, the quality and appearance of teaching aids, the benefits of the tools in learning, and the availability of tools and materials. The results of the validity test can be seen in Table 5 which shows the final score of 93%. Based on this score, this teaching aid is categorized as very valid and can be continued at the next research stage (Arikunto, 2011). The score also shows that this teaching aid can be used in light diffraction learning as a visualization tool, as researched by Mesic et al.

In this validity test, suggestions and input were also obtained from the validators to improve the teaching aids to make them even better. The validator input applied to this teaching aid is the coating of the body of the teaching aid using denser materials, as well as the use of a more natural and non-porous color capture screen. On the surface of the body, balsa wood with a thickness of 1 mm is used as a cardboard coating to make it more study, while the capture screen is coated with white sticker paper. The difference in the appearance of the teaching aids before and after the validity test is carried out can be seen in the following figure.

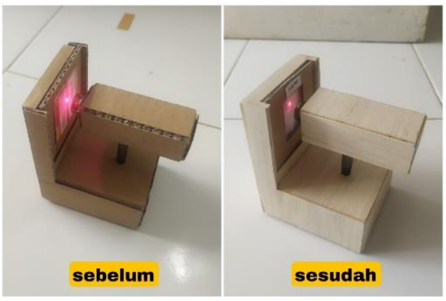


Fig 3. *Repair Props*

3. Practicality Test

This practicality test was conducted to determine the practicality of teaching aids using a questionnaire in which there are four aspects of assessment, namely usefulness, ease of use, ease of learning, and satisfaction which were adapted from Festiana et al. (2019). This practicality test questionnaire was filled out by 6 students of Physics Education FKIP University of Lampung who had taken optical courses. The small group test data was collected using the Zoho form by entering 20 questions into it. The results of the practicality test of this teaching aid obtained a final average score of 89% which, based on Arikunto (2011), was categorized as very good or showed that this simple light diffraction teaching aid that had been developed was very practical to use.

The practicality test also provides a representation that this light diffraction teaching aid is flexible to use, where students can modify the response variable and the dependent variable on the teaching aid. In addition, this teaching aid can also be used in other physical optical experiments such as light interference and polarization. However, the user needs to replace the diffraction grating with another material according to the experiment to be carried out. This is in line with the research of Khoa and Bang (2019), that physics learning media such as practicum tools are generally designed in such a way that they have a permanent structure. This permanent structure can indeed save time in preparing it, but it is not good if it is used to develop experiments, as well as the creativity and skills of students.

4. Student Response Test

The student response test was conducted to determine the effectiveness of the simple light diffraction teaching aid that had been developed. The process of collecting student response data is done online through the zoho form. The student response questionnaire consists of 15 questions that represent each indicator of the science process skills used, namely observing, measuring, communicating, controlling variables, hypothesizing, experimentation, and interpreting data adapted from Zeidan and Jayosi (2015). The results of the analysis of the student response test data were filled out by 16 respondents and showed that the final average score obtained was 86%. This value indicates that this simple light diffraction teaching aid is very good Arikunto (2011) or very effective if used in learning.

5. Teacher's Perception Test

The teacher's perception test also aims to determine the effectiveness of the simple light diffraction teaching aids that have been developed. The teacher's response questionnaire consists of 15 questions which also represent each indicator of the science process skills used, namely observing, measuring, communicating, controlling variables, hypothesizing, experimentation, and interpreting data. This teacher perception test was conducted online through the zoho form by 5 teachers from several schools. The results of the analysis of the teacher response test data showed that the final average score obtained was 84%. This value indicates that this simple light diffraction teaching aid is very good Arikunto (2011) or in this study is very effective if used in learning light diffraction material,

The use of simple light diffraction props can certainly help teachers in teaching abstract light diffraction concepts to students. This is in accordance with the results of research that physics is considered a difficult subject and burdensome for educators in several studies, this is because physics naturally consists of mathematical calculations based on interrelated physics concepts (Colak and Erol, 2020). Teaching aids are a very important teaching tool, teaching aids can make it easier to explain and develop a lesson theme (Shabiralyani et al., 2015).

This simple light diffraction teaching aid was developed so that it can be used to analyze light diffraction patterns, and can assist teachers in training science process skills (KPS) to students. Indicators of science process skills can be displayed with the help of these simple light diffraction props in the learning process. Observing indicators are carried out by observing activities before carrying out experimental activities, generally the teacher will give stimulus to students first. The stimulus can be in the form of photos, videos or explanations related to the material being discussed. At this stage, students will carry out observing activities by utilizing their senses to observe, record the nature or situation of the object to be observed. Hypothesizing indicators are carried out by providing their hypotheses about how the lattice distance to the screen affects, as well as the effect of grating size on the diffraction pattern. The controlling variables indicator is marked by students determining the distance and size of the grid to be used. Experimentation indicators are manifested in experimenting activities using simple light diffraction props that have been made. Measuring indicators can be done by analyzing experimental data using the tracker application. The communicating indicator is marked by students being able to present experimental data using graphs or tables generated in the tracker application. The last indicator is data interpreting, which means that interpreting the data can be done with participants doing an analysis based on experimental data obtained from observations using simple light diffraction props that were developed.

CONCLUSION AND SUGGESTION

This simple teaching aid can be used as a tool in digitally visualizing light diffraction patterns. The design of this teaching aid, apart from helping teachers explain light diffraction material which is considered abstract, is also intended to be able to train students' science process skills through direct experimentation. Several indicators that can be raised when using this teaching aid are formulating hypotheses, determining variables, taking measurements, interpreting data, and presenting data in the form of graphs and tables.

The development of this teaching aid is expected to be able to help overcome the problems of students' learning difficulties in light diffraction material. The materials used in the manufacture of these props also use simple materials and are combined with several electronic devices. This is intended to reduce costs and make it easier for teachers or educators who want to design similar tools in the future.

In future research, it is better to use a cheaper type of Arduino in order to reduce costs. The material for making the tool body should also be replaced with a more sturdy material in order to minimize damage when the tool is dropped. The laser used can use other colors to have variations in the measurement data. This certainly can increase students' knowledge when they analyze the experimental data that has been carried out.

REFERENCES

[1] National Science Foundation (US). Directorate for Education, & Human Resources. (1996). *Shaping the future: New expectations for undergraduate education in science, mathematics, engineering, and technology* (Vol. 1). National Science Foundation, Division of Undergraduate Education.

[2] Shanmugavelu, G., Balakrishnan, A., Parasuraman, L., Ariffin, K., Kannan, B., & Vadivelu, M. (2020). Inquiry method in the teaching and learning process. *Shanlax International Journal of Education*, *8*(3): 6-9.

[3] Hırça, N. (2017). The influence of hands on physics experiments on scientific Process skills according to prospective teachers' experiences1. *European Journal of Physics Education, 4*(1): 6-14.

[4] Redhana, I. W. (2019). Developing 21st century skills in chemistry learning. *Journal of Chemical Education Innovation*, *13*(1): 2239-2253.

[5] Lestari, M. Y., & Diana, N. (2018). Keterampilan proses sains (KPS) pada pelaksanaan praktikum Fisika Dasar I. *Indonesian Journal of Science and Mathematics Education*, *1*(1): 49-54.

[6] Ergül, R., Şımşeklı, Y., Çaliş, S., Özdılek, Z., Göçmençelebı, Ş., & Şanli, M. (2011). The Effects of Inquiry-Based Science Teaching on Elementary School Students' Science Process Skills and Science Attitudes. *Bulgarian Journal of Science & Education Policy*, *5*(1).

[7] Dönmez, F., & Azizoğlu, N. (2010). Investigation of the students science process skill levels in vocational schools: a case of Balıkesir. *Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education*, *4*(2): 79-109.

[8] Ateş, Ö., & Eryilmaz, A. (2011, June). Effectiveness of hands-on and minds-on activities on students' achievement and attitudes towards physics. In *Asia-Pacific Forum on Science Learning and Teaching* (Vol. 12, No. 1, pp. 1-22). The Education University of Hong Kong, Department of Science and Environmental Studies.

[9] Hegarty-Hazel, E. (1990). The student laboratory and the science curriculum: An overview. *The student laboratory and the science curriculum*, *3*: 26.

[10] Colombo, E. M., Jaen, M., & de Cudmani, L. C. (1995, October). Concept of coherence of learning physical optics. In *1995 International Conference on Education in Optics* (Vol. 2525,

pp. 452-458). SPIE.
[11] Setiawan, A., Pursitasari, I. D., & Hardhienata, H. (2018). Pengembangan kit praktikum difraksi dan interferensi cahaya untuk meningkatkan penguasaan konsep dan kemampuan berpikir kritis. *Edusentris*, *5*(1): 1-13.
[12] McDermott, L. C. (2000). Bridging the gap between teaching and learning: the role of physics education research in the preparation of teachers and majors. *Investigações em Ensino de Ciências*, *5*(3): 157-170.
[13] Mešić, V., Hajder, E., Neumann, K., & Erceg, N. (2016). Comparing different approaches to visualizing light waves: An experimental study on teaching wave optics. *Physical Review Physics Education Research*, *12*(1): 010135.
[14] Arsyad, A. (2011). *Media Pembelajaran*. Jakarta: Rajawali Press.
[15] Annur, S., Wati, M., Wahyuni, V., & Dewantara, D. (2019, July). Development of simple machines props using environmentally friendly materials for junior high school. In *6th International Conference on Educational Research and Innovation (ICERI 2018)* (pp. 363-367). Atlantis Press.
[16] Tafonoa, T. (2018). The Role of Learning Media in Increasing Students' Interest in Learning. *Journal of Educational Communication*, *3*(2): 103-114.
[17] Muhson, A. (2010). Development of information technology-based learning media. *Indonesian Journal of Accounting Education*, *8*(2): 1-10.
[18] Wati, M., Hartini, S., Hikmah, N., & Mahtari, S. (2018, March). Developing physics learning media using 3D cartoon. In *Journal of Physics: Conference Series* (Vol. 997, No. 1). IOP Publishing.
[19] Vollmer, M., & Möllmann, K. P. (2012). Low cost hands-on experiments for Physics teaching. *Latin-American Journal of Physics Education*, *6*(1): 3-9.
[20] Sariyanto, E., Suciyati, S. W., Pauzi, G. A., & Junaidi, J. (2014). Pengukuran Panjang Gelombang Sumber Lampu Monokromatis dari Pola Difraksi Cahaya Berbasis Webcam dan Borland Delphi. *Jurnal Teori dan Aplikasi Fisika*, *2*(2): 199-204.
[21] Ahmad, U. (2009). *10 Langkah Membuat Program Pengolah Citra Menggunakan Visual C#*. Yogyakarta: Graha Ilmu.
[22] Richey, R. C., & Klein, J. D. (2007). *Design and development research: Methods, strategies, and issues*. London: Lawrence Erlbaum Associates.