JURNAL PEMBELAJARAN FISIKA

http://jurnal.fkip.unila.ac.id/index.php/JPF

Vol 10 (2), 2022, 229-245 ISSN: 2302-0105 (p); 2684-9828 (e)

Development Of Physics Props For Arduino Uno-Based Light Wavelength Gauges With Diffraction Lattice Method (Case Study of Visible Light Wavelengths)

Rena Herdiana*, Aripin, Ifa Rifatul Mahmudah

Universitas Siliwangi, Indonesia

** e-mail: 182153037@student.unsil.ac.id*

Received: October 25, 2022 *Accepted: January 10, 2023* *Published: January 10, 2023*

Abstract: Research has been carried out on the development of physics props for measuring light wavelengths based on Arduino Uno with the diffraction lattice method (case study of visible light wavelengths), with the aim of determining the level of validity and practicality of arduino uno-based light wavelength measuring physics props with the diffraction lattice method. This research includes development research, with reference to the ADDIE development model with stages, namely analysis, design, development, implementation, and evaluation. The testing of props is carried out with validity tests by media experts and material experts to determine the level of validity of the props that have been developed. In addition, product trials were also carried out to determine the level of practicality of teaching aids, through student response tests and assessments from physics teachers. Product trials were carried out at sma class XI MIPA with a total sample of 163 people. Based on the results of the validity test of media experts and material experts, it can be known that the level of validity of props is on very valid criteria with a percentage of 85.71% from media experts and 95.69% from material experts. Then, based on the results of practicality tests carried out through student response tests, it can be known that the level of practicality of teaching aids is on practical criteria, with a percentage of 78.74%. Meanwhile, based on the results of practicality tests conducted through physics teacher assessments, it can be known that the level of practicality of teaching aids is on very practical criteria with a percentage gain of 84.28%. Based on the results of this study, it can be concluded that the physics props of arduino uno-based light wavelength measuring with the diffraction lattice method meet the criteria very valid and practical for use in the physics learning process.

Keywords: Physics Props, Arduino Uno, Light Wave, Diffraction grid.

DOI: http://dx.doi.org/10.23960/jpf.v10.n2.202207

INTRODUCTION

Since mid-2013, learning activities in Indonesia have implemented learning activities that refer to the 2013 Curriculum. In the 2013 Curriculum, each learning process is oriented towards a scientific approach with the characteristics of the learning stages consisting of activities of observing, questioning, reasoning, trying and communicating (Permendikbud, 2013). According to Novili et al (2017), by implementing the stages of learning activities, it will create a learning process that is student-centered, because at each stage it always involves students.

In essence, the stages of learning a scientific approach are widely used in science learning, including physics subjects. Physics is a part of science that discusses many concepts, laws and theories about natural phenomena that occur. Such various concepts, laws and theories are the result of a scientific product. On that basis, physics learning must be built through three elements of science, namely the scientific process, scientific attitudes, and scientific products (Fitriyah, 2019). Therefore, in the process of learning physics, both methods, processes, principles, attitudes and others will be very relevant if they implement the stages of learning contained in the scientific approach (Sumiati et al., 2018). However, some of the concepts of physics studied at school are abstract, so there are still many students who think that these concepts are difficult to understand (Kause & Boimau, 2019). Therefore, in order for students to easily understand the concept, it is necessary to have innovations that must be made by teachers in learning, both regarding learning methods and media (Setiawan et al, 2018). One strategy that can be applied is to utilize learning media that can provide understanding to students through skills training and hands-on experience.

One of the learning media that can be used in physics learning and is able to accommodate abstract physics material concepts is teaching aids (Muji et al., 2020). Teaching aids are a supporting tool used in learning activities, which aims to provide concrete examples of the learning material being studied (Setiawan & Mahmud, 2020). Based on the previous presentation, the scientific approach learning stage consists of observing, questioning, reasoning, trying and communicating activities. With these learning stages, especially in observing and trying activities, students are invited to get closer to the object being studied so that they can relate the relationship between the material taught and the concepts contained in the teaching aids (Nuvitalia et al., 2016). Therefore, the use of teaching aids in the physics learning process is expected to be able to meet the demands of the 2013 Curriculum which is oriented towards a scientific approach. However, the lack of teaching aids in schools and the lack of use of teaching aids in the physics learning process are problems in itself (Mujasam et al., 2018).

Based on the results of observations and interviews at SMAN 3 Tasikmalaya, the learning process is still rarely assisted by teaching aids, so the learning process carried out only applies the lecture method, and only uses the package books available as learning media. In addition to conducting observations and interviews, researchers also distributed questionnaires through the google form platform to 34 students who were representatives of three classes in class XII mipa at the school. The results of the questionnaire showed that 82% of students gave statements that they still felt difficulty in understanding the physics material presented, especially abstract material. This is because the learning method used only uses the lecture method and is rarely assisted by learning media in the form of teaching aids. After being identified, with this method, the physics learning process is still not as expected because it has not been able to meet the learning demands of the 2013 curriculum which is oriented towards a scientific approach. The results of the questionnaire also showed that 85% of students gave a statement that learning physics on light wave material needs to be assisted by using learning media in the form of teaching aids.

On the basis of the above problems, one of the right efforts to answer these problems is to develop physics props as a learning medium. In line with this, light wave matter is also included in abstract material, so it will be more effective if it is supported by props in the process of conveying the concept (Suryaningtyas et al, 2020). In the process of demonstrating or visualizing the concept of light, it often involves measurements such as measuring the wavelength of light. In measuring the wavelength of light so far, most of them still use manual methods or tools as well as using a ruler, so the measurement process is sometimes still ineffective (Syahputra et al, 2015). Based on the results of observations at SMAN 3 Tasikmalaya, a practicum kit that can be used to measure light wavelengths is an optical practicum kit whose one component is a diffraction grid. But in the measurement process, it still uses manual measuring instruments such as rulers. Therefore, to facilitate the measurement process, it is necessary to develop by utilizing digital tools that can be integrated directly in one system.

Along with the advancement of science and technology, many electronic devices produced that is beneficial to the world of education and can certainly be used for the development of physics props. Some examples of electronic devices that can be used for the development of physics props are microcontrollers, detector devices or sensors, display devices or LCDs, actuator devices and other devices. With these electronic devices, the physics props produced will be more effective, efficient, have better accuracy of measurement results, and visualization (Kause & Boimau, 2019).

Based on the description above, the researcher intends to conduct research on the development of physics props on light wave matter that can demonstrate the phenomenon of diffraction while being able to measure the wavelength of light. In the development of these props, researchers use the main electronic device, namely the Arduino Uno microcontroller kit, because in addition to having high performance and accuracy, this microcontroller kit can also be easily obtained at a fairly affordable price. As for the light source used, it is visible light, because in addition to being included in the subject matter of physics in high school, visible light sources can also be easily obtained, namely by using laser beams. Therefore, in this study, the researcher raised the title "Development of Physics Props for Measuring Light Wavelengths Based on Arduino Uno With the Diffraction Lattice Method (Case Study of Visible Light Wavelengths)", with the aim of knowing the level of validity and practicality of physics props for arduino uno-based light wavelength meters that have been developed.

METHOD

In this development research, the method used is the R&D (Research and Development) method. According to Sugiyono (2019), the R&D method is a method used in research with the aim of producing a certain product and testing the effectiveness of the product. As for the development model itself, researchers adapted the ADDIE development model that had been developed by Dick and Carey (1996). The

ADDIE development model was chosen based on the consideration that the stages of this model are simple as well as systematic. The stages of the ADDIE development model include: Analysis, Design, Development, Implementation, and Evaluation. Based on the selected development model, this research procedure follows the stages of the ADDIE development model as can be seen in figure 2.

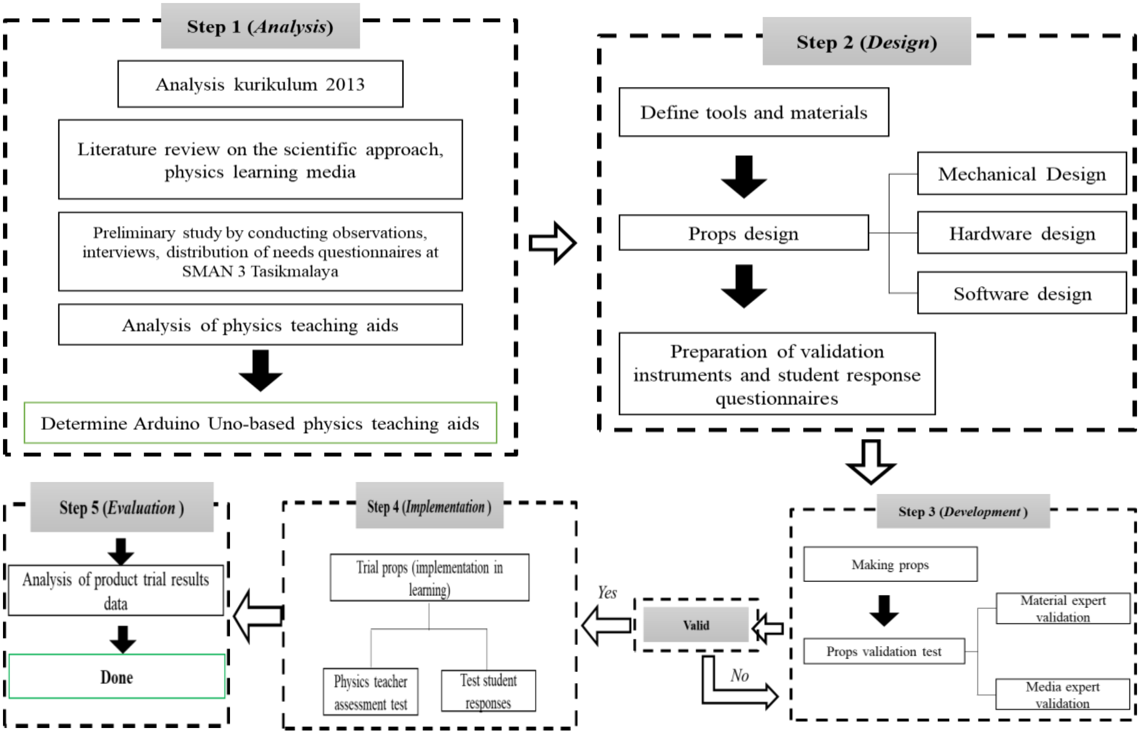

Figure 1. Stages of Research and Development

The testing of the tool is carried out with a validity test and a practicality test. The validity test is carried out by asking for values and responses from media experts, material experts, to find out the level of validity of the props along with the guidebook that has been developed. Meanwhile, the practicality test is carried out by distributing questionnaires to physics teachers and students to find out the assessment of physics teachers and the responses of students.

The validity instrument of the experts used in this study consists of several questions whose answers use the rating scale method. In the instrument, four categories of answer choices are given along with the provisions: a score of 4 (very good), 3 (good), 2 (less good), 1 (not good). Data acquisition from the validity instruments of experts was then analyzed using the following equation (Sugiyono, 2019).

$$Persentase\ (\%) = \frac{A}{B} \times 100\%$$

keterangan: A = skor hasil perolehan data

B = skor ideal

The percentage results obtained are then converted into a qualitative scale based on the criteria contained in the following table.

Table 1. Validity Criteria (Modification: Masyruhan et al., 2020)

Score Interval (%)	**Validity Level**
81,26% - 100,00%	Very Valid
62,51% - 81,25%	Valid
43,76% - 62,50%	Invalid
25,00% - 43,75%	Very Invalid

Table 2. Physics Teacher Assessment Criteria and Student Response (Modification: Masyruhan et al., 2020)

Score Interval (%)	**Practicality Level**
81,26% - 100,00%	Very Practical
62,51% - 81,25%	Practical
43,76% - 62,50%	Impractical
25,00% - 43,75%	Very Impractical

The props that have been developed are in the valid and practical category if they obtain a minimum score of 62,51% so that they can be used in the learning process.

RESULT AND DISCUSSION

The process of developing physics props in this study uses the ADDIE development model with the stages of Analysis, Design, Development, Implementation, and Evaluation. The description of the process of implementing the entire stage in this study is as followsall.

a. Analysis

Based on the results of observations and interviews at SMAN 3 Tasikmalaya, the learning process is still rarely assisted by teaching aids, so the learning process carried out only applies the lecture method, and only utilizes package books available as learning media. The results of the questionnaire showed that 82% of students gave statements that they still find it difficult to understand the physics material presented, especially abstract material. From the results of the questionnaire, it also showed that 85% of students gave a statement that learning physics on light wave material needs to be assisted by using learning media in the form of teaching aids.

b. Design

1. Mechanical Design

In the mechanical design there are two parts. The first part, utilizes wooden boxes to store breadboards and Arduino uno circuit boards. On one side of the box, there are four holes, each of which is used for the Arduino USB port, the LDR sensor cable for the stepper motor cable and the power cable. At the top of one side, there are also two holes for the push button holder.

While the second mechanical design section, serves as a visualization medium to demonstrate the visible light beam (laser) fired on the diffraction grid. The laser beam fired on the diffraction grating, aims to obtain the phenomenon of diffraction from the visible light beam (laser) so that a wavelength measurement of the visible light can be carried out. This section utilizes PVC pipes to make laser mounts, diffraction grids, stepper motors, and also LDR sensors. Broadly speaking, the mechanical design of these props is shown in the following figure

2. Hardware Design

The hardware design of these props includes a series of hardware that will be used in the manufacture of props. Broadly speaking, the hardware design of these props is shown in figure 3. The hardware design of this props, uses several components consisting of Arduino Uno, stepper motor, ULN2003 motor driver, LDR (Light Dependent Resistant) sensor, breadboard, push button, resistor, and jumper cable.

3. Software Design

The software design in this study was carried out by programming on arduino software. Broadly speaking, the software is designed as in the flowchart which can be seen in figure 4.

As seen in the flowchart, the device first declares the arduino library, the arduino pins and their variables. After that, the creation of a program is carried out in order to set the main function of the props as a counter to the intensity of the light captured by the light sensor. The program will enable the LDR sensor to be used as a light intensity gauge resulting from the diffraction grid flexing process. Meanwhile, the stepper motor programming is intended as an actuator used to drive the LDR sensor mechanically. In addition, serial programming of the monitor is also carried out to create a data acquisition system, so that data from arduino can be displayed in Microsoft Excel. The programs that have been created, will be executed with the instructions of the push button. There are two push buttons, the first for the "START" button and the second for the "RESET" button.

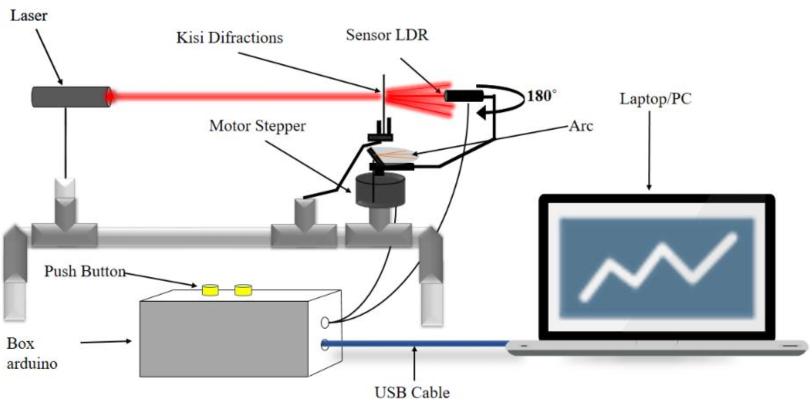

Figure 2. Mechanical Design of Props

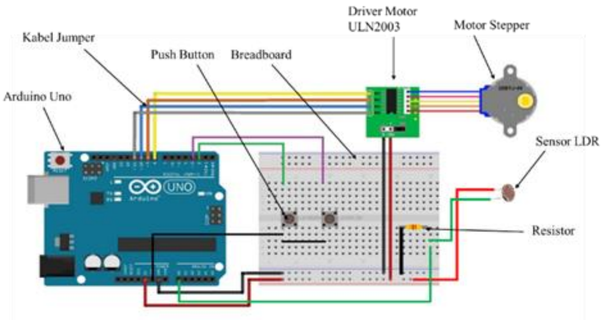

Figure 3. Hadrware Design of Props

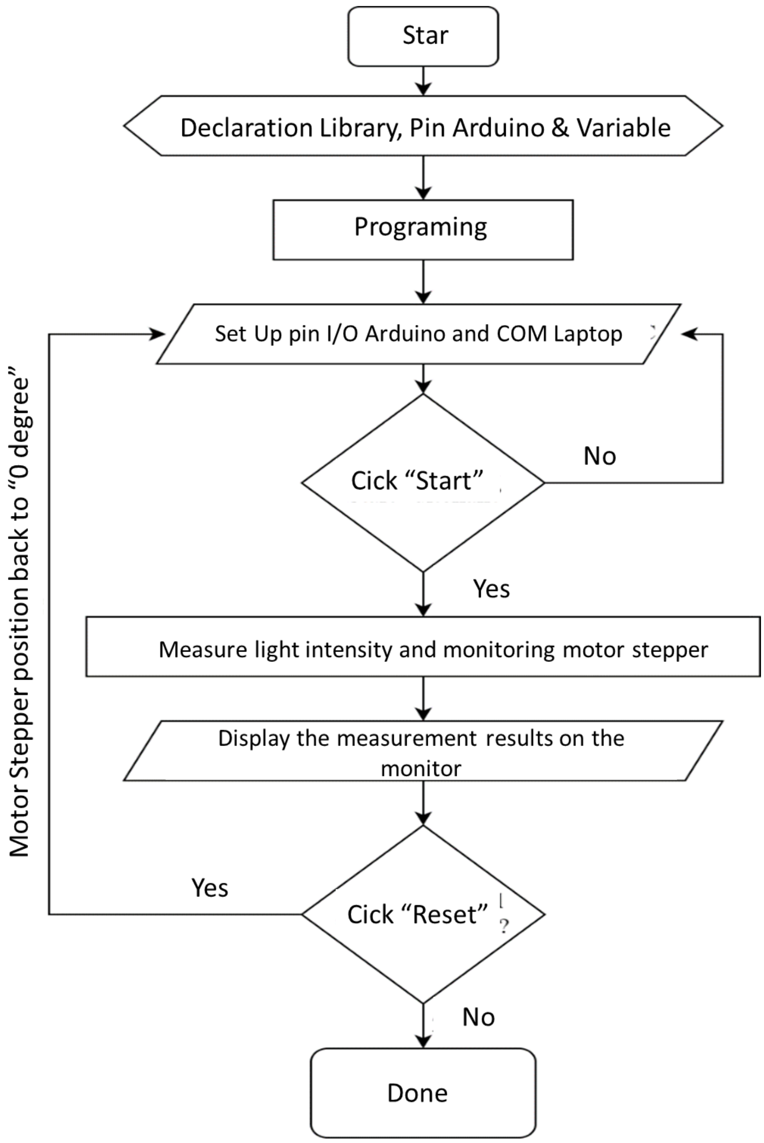

Figure 4. Props Software Flowchart

c. Development

The development stage is the realization stage of the product design that has been made. Broadly speaking, at this stage, product manufacturing and validity tests are carried out which will be described in the following description.

1. Product manufacturing

The products made at this stage are in the form of props along with a manual book (guidebook) for the use of props. The results of making products are divided into several parts including:

a) Product Manufacturing Result

The first part, the manufacture of arduino boxes made of wood which serves to store arduino uno circuit boards, breadboards and their components. On one side of the box, there are four holes, each of which is used for the Arduino USB port, the LDR sensor cable for the stepper motor cable and the power cable. At the top of one side, there are also two holes for the push button holder. The appearance of the Arduino box can be seen in the following pictures.

The second part is the creation of a visualization medium to demonstrate the phenomenon of diffraction. This section utilizes PVC pipes to make pointer holders, diffraction grids, stepper motors, and also LDR sensors. The appearance of the visualization media can be seen in the following pictures.

Figure 5. Arduino Box Display Front View

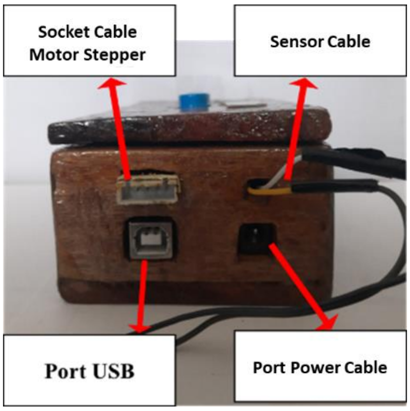

Figure 5. Arduino Box Display Side View

Figure 7. Arduino Box Display Looks In View

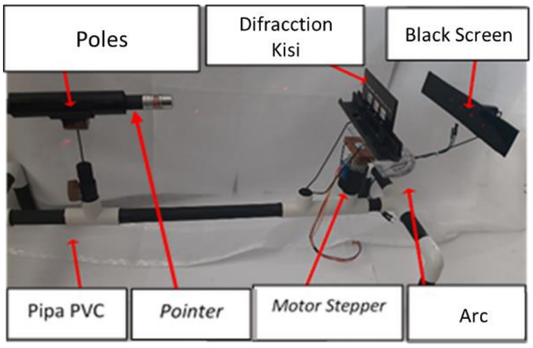

Figure 8. Visualization Media

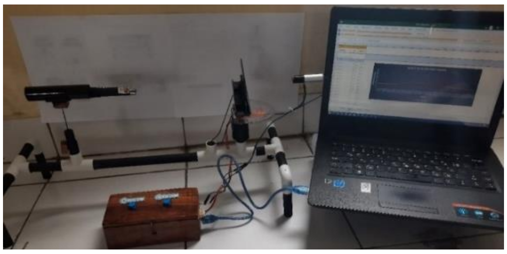

Figure 9. Overall View of Props

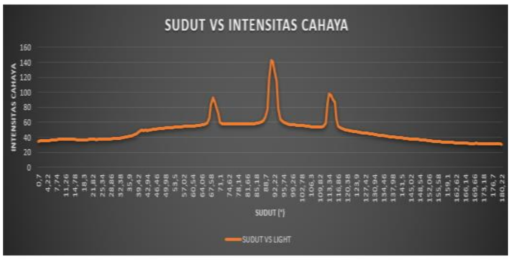

Figure 10. Serial Display

b) Results of Manual Book Creation

The manual book or guidebook for the use of props is made to provide usage guides to users of props that have been developed. Broadly speaking, the manual book presents a summary of the material, instructions for the use of props and experimental procedures for measuring the wavelength of light using props.

2. Validity Test

a) Media Expert Validity Test Results

The media expert validity test process is carried out by providing product assessments by three media expert validators. There are two products that are assessed, namely props and manual book props. Each validator provides an assessment of the product that has been developed, with 5 aspects of the assessment consisting of tool durability, tool accuracy, tool effectiveness, safety for learners and a kit box or storage box. As for the manual book, there are 2 aspects of assessment consisting of the appearance and feasibility of the language. The result data of each media expert validator can be seen in figure 11 and figure 12.

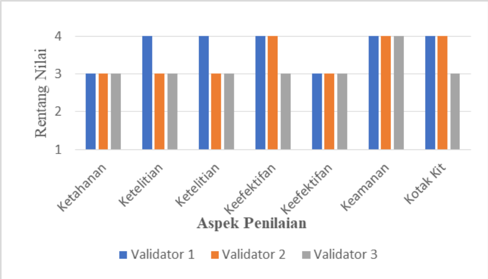

Figure 11. Media Expert Validity Test Results on Props

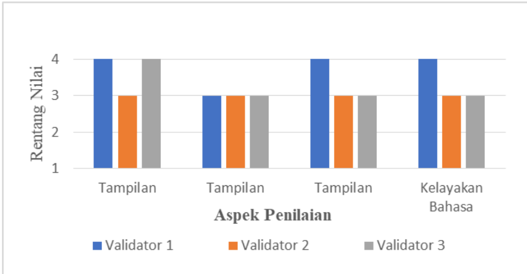

Figure 12. Media Expert Validity Test Results against The Props Manual Book

As for the details of the results of the media expert validity test, it can be seen in table 3.

Table 3. Media Expert Validity Test Results

No	Assessment Aspects	Score Acquisition	Ideal Score	Percentage	Criteria
Alat Peraga					
1	Tool Durability	9	12	75%	Valid
2	Tool Accuracy	20	24	83,33%	Very Valid
3	Effectiveness of the Tool	20	24	83,33%	Very Valid
4	Safety for learners	12	12	100%	Very Valid
5	Kit Boxes	11	12	91,67%	Very Valid
Manual Book					
6	Views	30	36	83,33%	Very Valid
7	Language Eligibility	10	12	83,33%	Very Valid
	Sum	112	132	599,99%	
	Average	16	18,85	85,71%	Very Valid

From the results of the media expert validity test, an average number of scores of 112 was obtained from the average ideal score of 132. The score obtained is then calculated using an equation so that an average percentage value of 85.71% is obtained. The results are then interpreted based on a table of validity criteria which can be seen in table 3.5. Based on the table, it can be concluded that the props that have been developed are on the criteria of "Very Valid".

The durability aspect of the tool obtaining a percentage value of 75% is on a valid criterion, where the resistance of each component of the props on the original stand is strong enough, not easily wobbled or loose. The aspect of the accuracy of the tool obtaining a percentage value of 83.33% is on a very valid criterion, where the props have been able to produce a clearly visible diffraction phenomenon and are able to be used to measure the wavelength of visible light with the resulting wavelength value in accordance with the theory. The aspect of the effectiveness of the tool obtaining a percentage value of 83.33% is on the very valid criteria, where the props developed are portable so that the components of the props can be disassembled and stored in the kit box. In addition, the props developed are easy to assemble according to the guidelines from the manual book. The safety aspect for students to obtain a percentage value of

100% is on very valid criteria, where the props developed do not have a component of the tool that can harm students. The aspect of the kit box obtaining a percentage value of 91.67% is on the very valid criteria, where the props are equipped with a kit box or storage box that can protect the props components from dust and moisture.The display aspect of the manual book obtained a percentage value of 83.33% is on very valid criteria, where the type and size of the letters can be read well the image can be seen clearly and the layout of the writing and images is appropriate. The aspect of language eligibility obtained a percentage value of 83.33% is on very valid criteria, where the language used in the manual book already uses good and correct Indonesian rules.

b) Material Expert Validity Test Results

The material expert validity test process is carried out by providing product assessments by three media expert validators. There are two products that are assessed, namely props and manual book props. Each validator provides an assessment of the product that has been developed, with 5 assessment aspects for props and 2 assessment aspects for the manual book. The 5 aspects of the teaching equipment assessment consist of tool durability, tool accuracy, tool effectiveness, safety for students and a kit box or storage box. Then for the assessment aspect, the manual book consists of the appearance and feasibility of the language.

The result data of each material expert validator can be seen in figure 13 and figure 14.

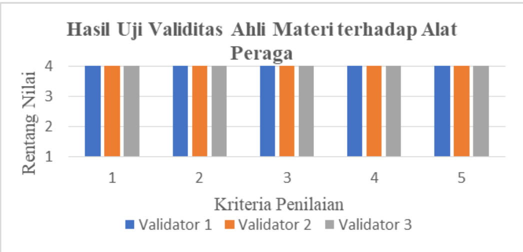

Figure 13. Material Expert Validity Test Results on Props

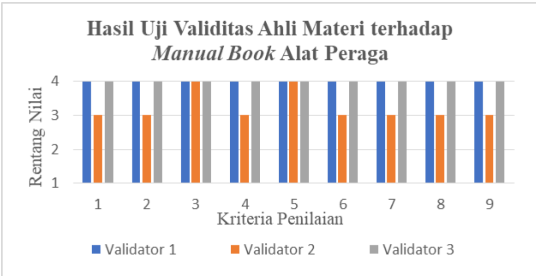

Figure 14. Material Expert Validity Test Results against the Props manual book

As for the details of the results of the material expert validity test, it can be seen in table 4.

Table 4. Material Expert Validity Test Results

No	Assessment Aspects	Score Acquisition	Ideal Score	Percentage	Criteria
Props					
1	Linkage with Teaching Materials	36	36	100%	Very Valid
2	Educational Value	24	24	100%	Very Valid
Manual Book					
3	Eligibility of Contents	57	60	95%	Very Valid
4	Eligibility of Presentation	33	36	91,67%	Very Valid
6	Language Eligibility	11	12	91,67%	Very Valid
	Sum	161	168	478,34%	
	Average	32,2	33,6	95,69%	Very Valid

From the results of the material expert validity test, an average number of scores of 161 was obtained from the average ideal score of 168. The score obtained is then calculated using an equation so that an average percentage value of 95.69% is obtained. The results are then interpreted based on a table of validity criteria that can be seen in table 2. Based on the table, it can be concluded that the props that have been developed are on the criteria of "Very Valid.

Aspects the relationship with teaching materials obtaining a percentage value of 100% is on very valid criteria, where the props are in accordance with the concept of light waves and can be used to explain the concept of diffraction. The aspect of educational value obtaining a percentage value of 100% is on very valid criteria, where props props are in accordance with the level of intellectual development of students and are able to foster student learning motivation. The feasibility aspect of the content obtaining a percentage value of 95% is on very valid criteria, where the material guidance contained in the manual book is in accordance with KD 4.10 (Physics grade 11) and in accordance with the concept of light waves. The results of the assessment also show that the assembly instructions have been able to provide convenience in the preparation of props and experimental procedures that have provided convenience in conducting experiments. The feasibility aspect of the content obtaining a percentage value of 91.67% is on very valid criteria, where what is contained in the manual book has been arranged systematically, in accordance with the concept of light waves and in accordance with the level of development of students. The content eligibility aspect obtained a percentage value of 91.67% is on very valid criteria, where the sentence structure used in the manual book is in accordance with the level of mastery of students.

d. Implementation

This stage is the product trial stage, by implementing products that have been developed in physics learning activities. The subjects of the research trial were students of class XI MIPA at SMAN 3 Tasikmalaya for the 2022/2023 school year with a student population of 276 people. Meanwhile, to determine the sample of the population, using the Slovin formula with a sampling error of 5%. The following is a breakdown of the results of the sample determination can be seen in table 5.

Table 5. Sample Determination Results

Jumlah Populasi	$n = \frac{N}{1 + N(e)^2}$	n
276	$n = \frac{276}{1 + 276(5\%)^2}$ $n = \frac{276}{1 + 276(0,0025)}$ $n = \frac{276}{1,69}$ $n = 163,31 \approx 163$	163

From the calculation results, the number of samples obtained amounted to 163 students.

The trial was carried out on August 8-10 of the year 2022, by demonstrating the product in front of students during physics learning activities. At the end of the learning process, students are asked to respond through the questionnaire given. The questionnaire is used for practicality testing, which aims to measure the level of practicality of the product that has been developed. The recapitulation data of the practicality test results can be seen in figure 15 and figure 16.

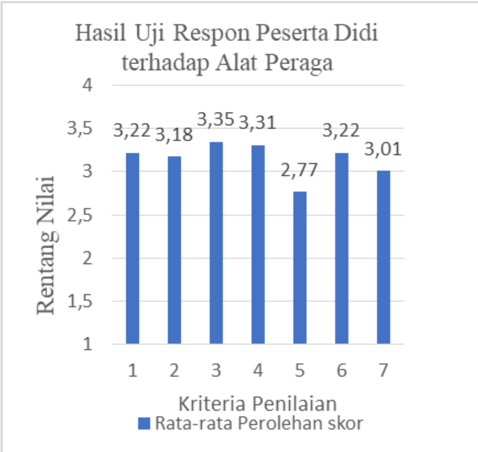

Figure 15. Results of the Student Response Test to The Props

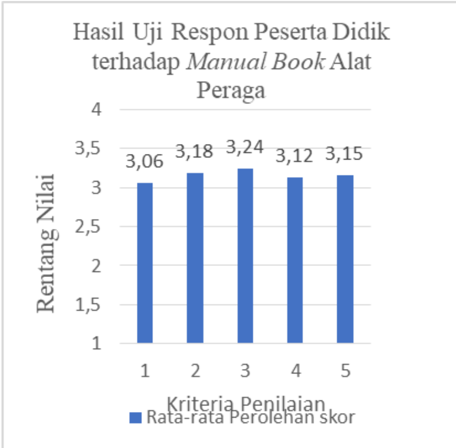

Figure 16. Results of the Student Response Test to the Teachings Manual Book

As for the details of the results of the student response test, it can be seen in table 5.

Table 5. Sample Determination Results

No	Product	Average Number of Scores Earned	Ideal Score	Percentage	Average Percentage
1	Props	22,06	28	$\frac{22,06}{28} \times 100\% = 78,79\%$	78,74%
2	Manual Book	15,74	20	$\frac{15,74}{20} \times 100\% = 78,70\%$	

From the results of the student response test, the average number of scores obtained for props was 22.06 from the ideal score of 28 and the average number of scores obtained for the manual book of props was obtained of 15.74 from the ideal score of 20. The score obtained was then calculated using equation, so that a percentage value of 78.79% was obtained for props and 78.70% for manual book props. Meanwhile, the overall average obtained a percentage value of 78.74%. The results are then interpreted based on a table of practicality criteria which can be seen in table 2 . Based on the table, it can be concluded that the props that have been developed are on the "Practical" criterion.

In addition to students, practicality tests are also aimed at physics teachers. The practicality test process by physics teachers is carried out by providing product assessments by physics teachers at SMAN 3 Tasikmalaya. Physics teachers give an assessment of the products that have been developed, by filling out a questionnaire consisting of 7 questions for props, and 4 questions for the props manual book. The data on the results of the physics teacher's assessment can be seen in the following figure 17 and figure 18.

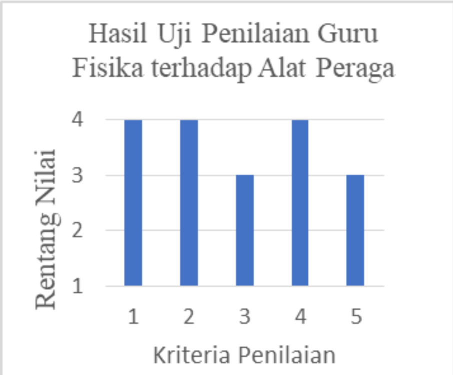

Figure 17. Physics Teacher Assessment Results on Props

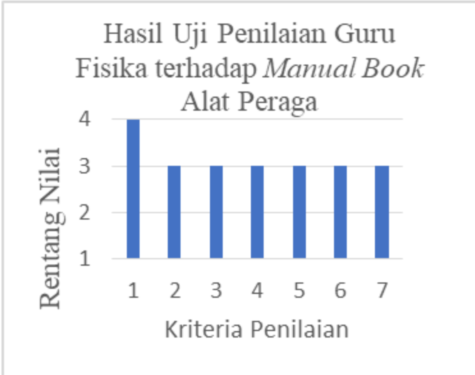

Figure 18. Physics Teacher Assessment Results on Manual Book Props

As for the details of the results of the physics teacher assessment, it can be seen in table 6.

Table 6. Physics Teacher Assessment Test Results

No	Product	Average Number of Scores Earned	Ideal Score	Percentage	Average Percentage
1	Props	18	20	$\frac{18}{20} \times 100\% = 90\%$	84,28%
2	Manual Book	22	28	$\frac{22}{28} \times 100\% = 78{,}57\%$	

From the assessment results of physics teachers, the average number of scores for props was obtained by 18 out of the ideal score of 20 and the average number of scores obtained for the manual book of props was obtained by 22 out of the ideal score of 28. The score obtained is then calculated using equation, so that a percentage value of 90% is obtained for props and 78.57% for manual book props. Meanwhile, the overall average obtained a percentage value of 84.28%. The results are then interpreted based on a table of practicality criteria which can be seen in table 2. Based on the table, it can be concluded that the props that have been developed are on the criterion of "Very Practical".

e. Evaluation

Based on the results of product trials, it can be known that the physics props for measuring light wavelengths based on Arduino Uno with the diffraction lattice method, have met the practical criteria for use in learning the physics of light wave material. As for the advantages of this prop, props are able to visualize the phenomenon of diffraction while being able to produce the data needed to measure the wavelength of light and are integrated directly in one system. However, from the results of product trials, it also shows that there are still many students who find it difficult to use props if done independently. This is a shortcoming in itself, so there needs to be a more detailed explanation regarding the use of teaching aids according to the reference from the manual book before conducting experiments, and there is a need for assistance from teachers in conducting experiments.

CONCLUSION

Based on the results of research and development of arduino uno-based light wavelength measuring physics props with the diffraction lattice method, the following conclusions can be obtained.

Based on the results of the media expert validity test, the validity level of the arduino uno-based light wavelength measuring physics props with the diffraction lattice method is on the "Very Valid" criterion, with a percentage gain of 85. 71%. Then, based on the results of the material expert validity test, the validity level of the arduino uno-based light wavelength measuring physics props with the diffraction lattice method is on the "Very Valid" criterion, with a percentage gain of 95.69%.

Based on the results of practicality tests conducted through student response tests, the level of practicality of arduino uno-based light wavelength measuring physics props with the diffraction lattice method is on the "Practical" criterion, with a percentage gain of 78.74%. Meanwhile, based on the results of practicality tests conducted through the assessment of physics teachers, the level of practicality of arduino uno-based light wavelength measuring physics props with the diffraction lattice method is on the "Very Practical" criterion, with a percentage gain of 84.28%.

REFERENCES

Direktorat Pembinaan, S. M. (2011). *Pedoman Pembuatan Alat Peraga Fisika untuk SMA.* Indonesia: Direktorat Pembinaan S.M.A Direktorat Jenderal Pendidikan Menengah Kementerian Pendidikan Dan Kebudayaan Tahun 2011.

Effendy, Onong Uchjana. (2017). *Ilmu Komunikasi Teori dan Praktek.* Jawa Barat: Rosda.

Fitriyah, L. (2019). *Pengembangan Alat Peraga Fisika Bernoulli Technology Untuk Meningkatkan Keterampilan Proses Sains Siswa.* Dinamika: Jurnal Praktik Penelitian Tindakan, 1-9.

Handayani, S., & Damari, A. (2009). *FISIKA untuk SMA dan MA kelas XII* . Jakarta: Pusat Perbukuan Departemen Pendidikan Nasional.

Haryato et al. (2020). *Pengembangan Kit Praktikum Gelombang Elektromagnetik untuk Meningkatkan Keterampilan Proses Sains Siswa* . Jurnal Edu Sains p-ISSN 2621-7953 p-ISSN 2621-7945, 9-17.

Kause, M. C., & Boimau, I. (2019). *Rancang Bangun Alat Peraga Fisika Berbasis Arduino (Studi Kasus Gerak Jatuh Bebas).* CYCLOTRON : JURNAL

Masyruhan et al. (2020). *Perancangan Alat Peraga Hukum Hooke Berbasis Mikrokontroler Arduino sebagai Media Pembelajaran Fisika*. SPEKTRA: Jurnal Kajian Pendidikan Sains 6 (20). doi:http://dx.doi.org/1032699/spektra.v6vi2i.145

Mirnawati et al. (2021). *Pengembangan Media Pembelajaran Buku Saku Berbasis Konflik Kognitif Untuk Meningkatkan Pemahaman Konsep dan Keterampilan Berpikir Kritis IPA (Fisika) Peserta Didik.* Jurnal Ilmiah Profesi Pendidikan, 447-454.

Muhsinun. (2021, July 09). *Apa itu Arduino, Pengertian dan Spesifikasi Arduino Uno R3*. Retrieved Juny 3, 2022, from Prevent: https://www.prevent.my.id/2021/07/apa-itu-arduino-pengertian-arduino.html

Muji, R., Wahyudi, M., & Zohdi, A. (2020). *Pengembangan Alat Peraga Gaya Elektromagentik Sebagai Solusi Media Pembelajaran Fisika Di Ma Al-Maarif Qomarul Huda Montong Ara*. KONSTAN JURNAL FISIKA DAN PENDIDIKAN FISIKA, 18-26.

Mujasam et al. (2018). *Penerapan Model PBL Menggunakan Alat Peraga Sederhana terhadap Hasil Belajar Peserta didik.* Jurnal Curricula e-ISSN 2502-0714, 11-22.

Novili, W. I., Utari, S., Saepuzaman, D., & Karim, S. (2017). *Penerapan Scientific Approach dalam Upaya Melatihkan Literasi Saintifik dalam Domain Kompetensi dan Domain Pengetahuan Siswa SMP pada Topik Kalor*. Jurnal Penelitian Pembelajaran Fisika, 58.

Nurjanah, S. (2017). *Pengembangan Alat Peraga Kalor Jenis pada Pokok Bahasan Suhu Dan Kalor Berbasis Arduino.* Purworejo: (Skripsi) Program Studi Pendidikan Fisika FKIP Universitas Muhammadiyah Purworejo.

Nuvitalia et al., D. (2016). *Analisis Kebutuhan Alat Peraga dalam Implementasi Kurikulum 2013 pada Mata Pelajaran IPA Terpadu*. Unnes Physics Education Journal, 60-65.

Permendikbud RI. (2013). *Standar Proses Pendidikan Dasar dan Menengah.* JAKARTA: Menteri Pendidikan dan Kebudayaan Republik Indonesia.

Pratiwi et al., (2018). *Penggunaan Metode User Centered Design (UCD) dalam Perancangan Ulang Web Portal Jurusan Psikolog FISIP Universitas Brawijaya.* Jurnal Pengembangan Teknologi Informasi dan Ilmu Komputer.

Prihatiningtyas, S., & Haryono, H. E. (2019). *Alat Peraga Sebagai Upaya Peningkatan Pemahaman Konsep Peserta didik Pada Materi Mekanika Fluida*. *Science Education Journal (SEJ)* ISSN 2540-9859 DOI: *https://doi.org/10.21070/sej.v3i2.3095, 131-138.*

Razor, A. (2020, July 07). *Belajar Bahasa Pemrograman Arduino Dasar Untuk Pemula*. Retrieved February 2, 2022, from ALDYRAZOR.COM: https://www.aldyrazor.com/2020/07/bahasa-pemrograman-arduino.html

Ridarmin et al. (2019). *Prototype Robot Line Follower Arduino Uno Menggunakan 4 Sensor Tcrt5000*. Jurnal Informatika, Manajemen dan Komputer eISSN : 2580-3042 pISSN : 1979-0694, 17-23.

Santoso, R et al. (2019). *Perancangan Buku Panduan Belajar Menggambar Untuk Anak Usia 4-6 Tahun*. Jurnal DKV Adiwarna, 1(6), 13.

Setiawan et al. (2018). *Pengembangan Kit Praktikum Difraksi Dan Interferensi Cahaya Untuk Meningkatkan Penguasaan Konsep Dan Kemampuan Berpikir Kritis*. Edusentris, Jurnal Ilmu Pendidikan dan Pengajaran, Vol. 5 No.1 Maret 2018.

Setiawan, D. G., & Mahmud, S. A. (2020). *Penerapan Alat Peraga Terhadap Hasil Belajar Siswa Pada Materi Gelombang Mekanik*. Jurnal Pendidikan Fisika Tadulako Online (JPFT) Vol. 8 No. 2, Agustus 2020 p-ISSN 2338-3240, e-ISSN 2580-5924, 49-51.

Siahaan, F. E. (2019). *Pengaruh Model Pembelajaran Inkuiri dengan Penggunaan Alat Peraga Fisika Terhadap Hasil Belajar Siswa Kelas X Semester II SMA.* BAHASTRA Jurnal Pendidikan Bahasa dan Sastra Indonesia ISSN: 2550-0848; ISSN Online :2614-2988, 348-354.

Sugiyono. (2019). *Metode Penelitian Kuantitatif, Kualitatif dan R&D.* Bandung: ALFABETA.

Sukarno, B. B. (2020). *Modul Pembelajaran SMA FISIKA Kelas XII.* Indonesia: Direktorat SMA, Direktorat Jenderal PAUD, DIKDAS dan DIKMEN.

Sumiati et al, E. (2018). *Pengembangan modul fisika berbasis Scientific Approach untuk meningkatkan Keterampilan Proses Sains siswa.* Jurnal Pendidikan Fisika dan Keilmuan (JPFK), 76.

Suryaningtyas et al. (2020). *Pengembangan E-modul Berbasis Android dengan Metode Fodem Pada Materi Gelombang Bunyi dan Gelombang Cahaya.* Prosiding Seminar Fisika 2020 (pp. 169-175). Jakarta: Universitas Negeri Jakarta.

Syahputra et al. (2015). *Pembuatan Alat Ukur penelitian Difraksi Cahaya Berbasis Vision Assistant dan Labview*. Prosiding Seminar Nasional Fisika 2015 (pp. 33-38). Jakarta: Universitas Negeri Jakarta.

Wahyuningsih, F. T., Al Hakim, Y., & Ashari. (2019). *Pengembangan Alat Peraga Pengukur Debit Air Menggunakan Sensor Flow Berbasis Arduino Sebagai Media Pembelajaran Fluida*. RADIASI: Jurnal Berkala Pendidikan Fisika, 38-45.