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WEB-BASED INTERACTIVE LEARNING MEDIA DEVELOPMENT USING P5.JS ON LIGHT AND OPTICAL DEVICE MODULE FOR HIGH SCHOOL COMPETENCY

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Abstract. This research was conducted with the aim of making an interactive learning module for light and optical devices adapted for school students, to improve the performance of education in Indonesia in the Program for International Student Assessment (PISA). By integrating simulation and interactive media using p5.js, students' understanding and engagement in the subject matter can be improved. The development process includes a comprehensive literature review, interactive object design, simulation creation, and analytical validation of the media by students and learning practitioners. The research also performed analytical calculations and compared the values with the simulated value, then get a fairly small coefficient correlation which is around 0,000427 - 0,021912; 0,003426 - 0.243858; 0,003298 - 0,082615; and 0,001004 - 0,183618 for the convex mirror, concave mirror, convex lens, and concave lens respectively. The effectiveness of the module was evaluated through pretest and posttest, practicality assessment by students, and review by learning practitioners at SMP Muhammadiyah 10 Bandung. The results of this research showed significant improvement in students' understanding and highlighted the practicality of the module in conveying complex scientific concepts. The research also highlighted the potential of interactive learning media in overcoming educational challenges, especially in science education, and suggests its broader application to improve learning outcomes in a variety of science fields.

Keywords: interactive learning media; mirror and lens simulation; light; optical devices

INTRODUCTION

Based on the results of the Program for International Student Assessment (PISA), Indonesia's education system is currently ranked 61st out of 81 countries evaluated, indicating room for improvement. The assessment takes into account various aspects of education. Literacy skills, which include reading, writing, and comprehension of text, are essential, as are numeracy and science skills. It is important to have a solid foundation in these areas (Arifa & Prayitno, 2019). To address the issue, the government has implemented SPADA Dikti, which stands for Indonesian Online Learning System. This program, managed by the Directorate General of Higher Education, provides online courses and distributes learning materials to respond to the challenges of teaching and learning during the pandemic. This program has the

potential to greatly support the development of learning media and address the challenges faced by higher education during these difficult times. In light of the current COVID-19 pandemic, it is worth considering the potential benefits of SPADA Dikti, an online course management program that is being provided free of charge by the government to higher education institutions and students (Hummaera & Bakry, 2023).

Learning media is a useful tool that can enhance teaching and learning activities by making the conveyed message clearer and helping to achieve learning objectives effectively and efficiently. It is important to maintain a balanced and objective approach to avoid bias and ensure precise word choice. When learning media is interesting and aligned with student needs, it can increase their attention to the lesson and consequently, their motivation to learn (Nurrita, 2018). PISA assesses science, which is a discipline consisting of physical science and life science, such as biology. Physics is typically taught as part of the science curriculum at the high school level. The key to studying science is understanding the underlying concepts, which can be achieved through experiment. However, simulation can be a solution due to limited laboratory equipment (Masita et al., 2020). The simulation is a technological innovation in the field of education that enables students to indirectly utilize learning technology, potentially making learning more engaging and effective (Maritsa et al., 2021).

Among the many topics studied at the high school level, the chapter on 'Light and Optical Devices' can be challenging, particularly when relying solely on lecture-based learning methods with the aid of blackboard media. It is recommended that the material can be presented in a clear and concise manner, using simple language and avoiding complex terminology. Additionally, it is important to maintain a logical flow of information with causal connections between statements. Therefore, it may be beneficial to provide learning media that make it easier for students to comprehend this complex subject matter (Suradnya et al., 2017). This research presents an interactive learning media for the light and optical devices module, which was developed using p5 JavaScript and HTML. The media includes simulations that are accessible online and were created independently. The aim of this project is to provide students with an engaging and effective learning experience.

Related Studies

In study (Rochim et al., 2019), the researchers investigated students' misconceptions about light using the forty-test method with the certainty of response index (CRI). Prior to this research, a literature review was conducted on relevant topics. The study revealed that science concepts related to light and optical devices can be challenging to comprehend. The subject of optical devices is multifaceted and may benefit from additional research and effective learning methods. According to a study, conducted in two junior high schools, an average percentage of misconceptions was found to be 38% in SMP Negeri 1 Ngadiluwih and 31% in SMP Negeri 1 Kediri.

Moreover, (Murtiani et al., 2019) conducted a study on light and optical devices intended for senior high school students to enhance their learning outcomes in physics, specifically in wave and optical materials. They utilized PowerPoint 2013 to develop interactive learning media. Based on the study, it can be inferred that interactive learning media is considered a highly practical tool, as evidenced by the positive test assessments of 93% from teachers and 82% from students.

Then, in (Prakasiwi et al., 2021), explored the development of learning media using Adobe Animate software. The study underwent validation by both media and material experts, as well as learning practitioners. It is worth noting that the average validations score from the media and material experts was 87.93%. The average score of 87.93% is categorized as 'very feasible'. Additionally, based on the assessment of learning practitioners, the learning media used also falls within the 'very feasible' category with an average score of 81.03%. In this

study, both student responses and expert validation were collected and analyzed. The average response rate among students was 76.93% and the data was categorized as ‘interesting’.

The study by (Murtiani et al., 2019) produced learning materials that include text, videos, sample questions, and evaluation questions. Similarly, (Prakasiwi et al., 2021) developed learning materials that consist of text, sample problems, practice problems, and questions. In addition to those researches, there are many other studies that discuss interactive learning media, such as (Penjor et al., 2022), which discussed the effectiveness of simulation in teaching ‘Geometric Optics’. The results showed that interactive media such as simulations can improve students’ concept understanding and practical skills. In (Alam et al., 2021), it also showed a positive and significant effect of simulation on the quality of physics learning.

RESEARCH METHOD

This research was conducted in several stages. These stages included conducting literature reviews, compiling materials and concepts, designing interactive media, validating simulation calculations with analytics, verifying and evaluating by learning practitioners and students, and producing reports. In regards to the learning media scheme, the main menu display will be divided into three sections: The material section, along with instructions on how to use it, will also be included. KD (basic competencies), KI (core competencies), and objectives. Upon selecting the KD, KI, objective sections, the KD, KI, and objectives of the light module and optical devices will be displayed. Furthermore, selecting the material section will reveal a variety of materials specifically designed for each meeting, utilizing different learning methods. In addition, the ‘how to use’ section offers guidance on utilizing the learning media, which encompasses the button functionalities. The interactive learning media was created using Coreldraw X8, p5 JavaScript, HTML, and Vegas Pro 18 software. The research was set to take place at the Instrumentation Laboratory of the Physics at Padjadjaran University and at SMP Muhammadiyah 10 Bandung or high school level.

Interactive Learning Media Scheme

Fig. 1 displays the main menu of the learning media, which consists of three sections: KD, KI, objectives, material section, and instructions. When selecting the KD, KI, objectives sections, the KD, KI, and objectives of the light module and optical devices will be revealed. Additionally, the material section contains various materials that have been designed for each meeting. The material has been thoughtfully divided into five parts, each utilizing different learning methods, and is accompanied by a competency test. The text is presented with additional animations and practice questions in the light properties section to enhance the learning experience. In the section on mirrors, the material is presented through various

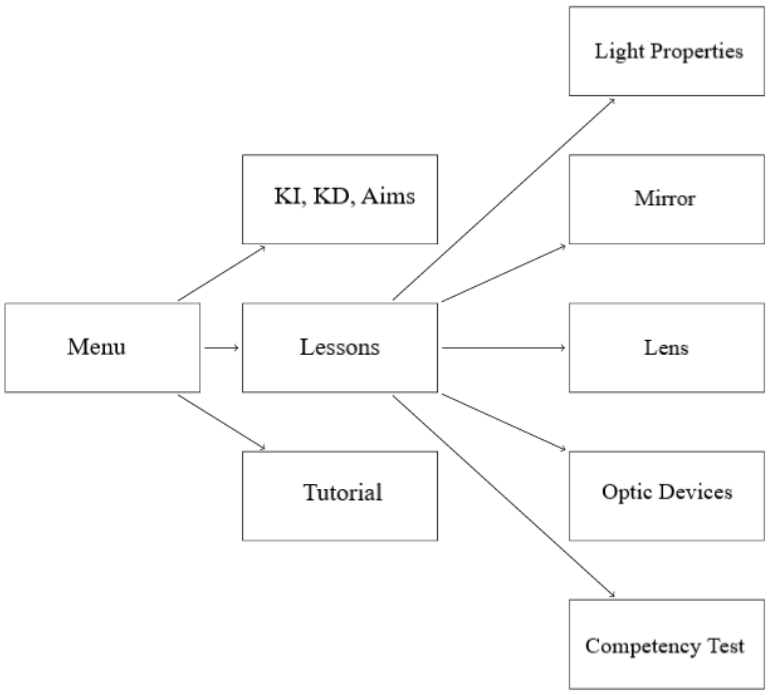


Figure 1. Interactive Learning Media scheme

methods such as text, simulation, example problems, and directions for independent practice in the forming shadows from two flat mirrors. Similarly, for

lenses, the material is presented through a range of resources including learning videos, simulation, sample problems, and practice problems. When discussing optical devices, the material is presented through text, along with a summary of the light module and optical devices. The competency test covers topics related to light and optical devices, as well as instructions on how to use learning media, including the functions of the buttons.

Teaching Methods

Every learner has different learning style tendencies whether it is through vision (visual), hearing (auditory) or moving and doing (kinesthetic). Learning style itself refers to the method or approach that is most effective for a person in receiving, processing and understanding new information (Pourhosein Gilakjani, 2011). Learning methods are steps or techniques for presenting learning materials that educators will use when presenting learning materials, either individually or in groups. Some learning methods that can be used to implement learning strategies include lectures, demonstrations, experiments, discussions, educational games, simulations and role playing (Hartini et al., 2022). In the world of education, there are the terms pedagogy and pedagogics. Pedagogy is the art of teaching which means one's talent. Everyone has different arts and styles in teaching. This style or art can be maximized through the science of teaching called pedagogics. Pedagogics focuses on contemplative thinking about education. As for pedagogy, it covers teaching practices such as teaching methods (e.g. lectures, discussions, or projects), use of learning media, curriculum development and implementation, learning evaluation and assessment, and classroom management. It also includes techniques to increase student learning motivation, differentiation of learning to meet the needs of diverse students, and strategies to support inclusive learning (Ningrum et al., 2023).

RESULTS AND DISCUSSION

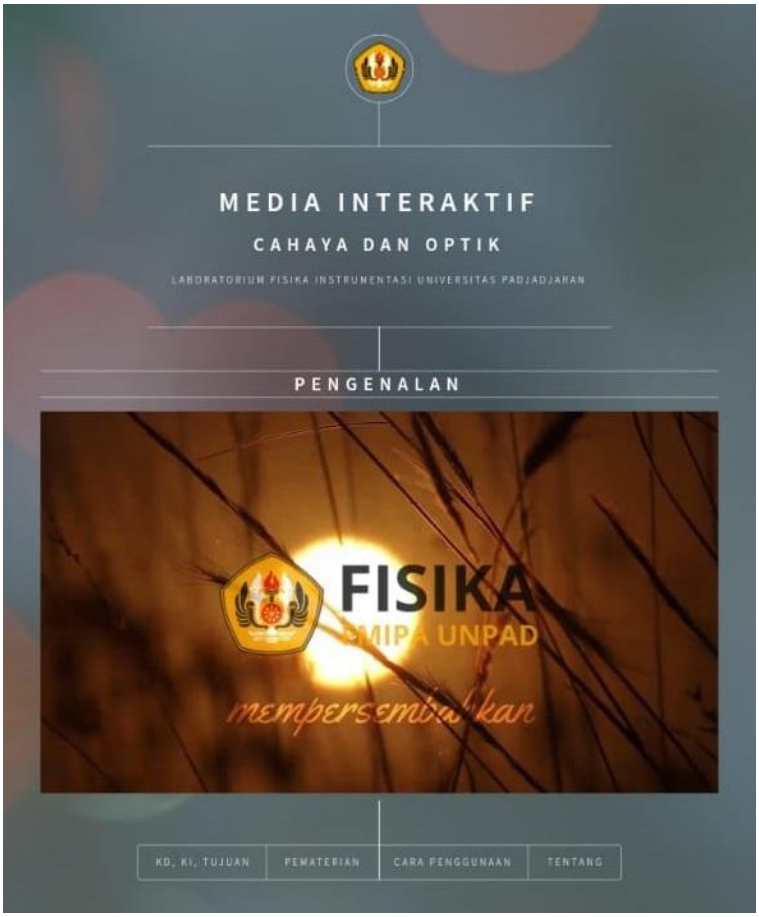


Figure 2.Learning Media menu display

Interactive learning media for the material "Light and Optical Devices" has been designed by following the basic competencies set by the government through the Ministry of Education and Culture (Kemendikbud) as part of the applicable curriculum. The basic competencies of the material "Light and Optical Devices" are analyzing the properties of light, the formation of shadows on flat and curved planes, the working principles of optical devices and presenting the results of experiments on the formation of shadows on mirrors and lenses. From Fig. 2, it can be seen that the initial display of interactive learning media contains an introduction video about the material, as well as buttons to go to other sections such as KI, KD, Objectives, then soldering, how to use and about. The KI, KD, and goal section buttons contain core competencies, fundamentals, objectives and achievement indicators for light and optical devices. Then in the "Theater" section, there is a button for each material which is divided into five parts, namely light waves, mirrors, lenses, optical devices and competency tests. In one interactive media, the material can be delivered by the teacher with several learning methods ranging from lectures, group discussions, questions and answers, cooperative learning such as practicum, and others.

In the light wave material section, the material is presented in the form of text assisted by images and simple animations. In addition to the material, the material provides practice questions about the properties of light in the form of multiple choice as many as 10 questions. Furthermore, in the mirror material section, the material is presented in text form assisted by images. In this section of mirror material, independent practice and simulation are also provided. Independent practice that can be done by students is the practice of forming shadows

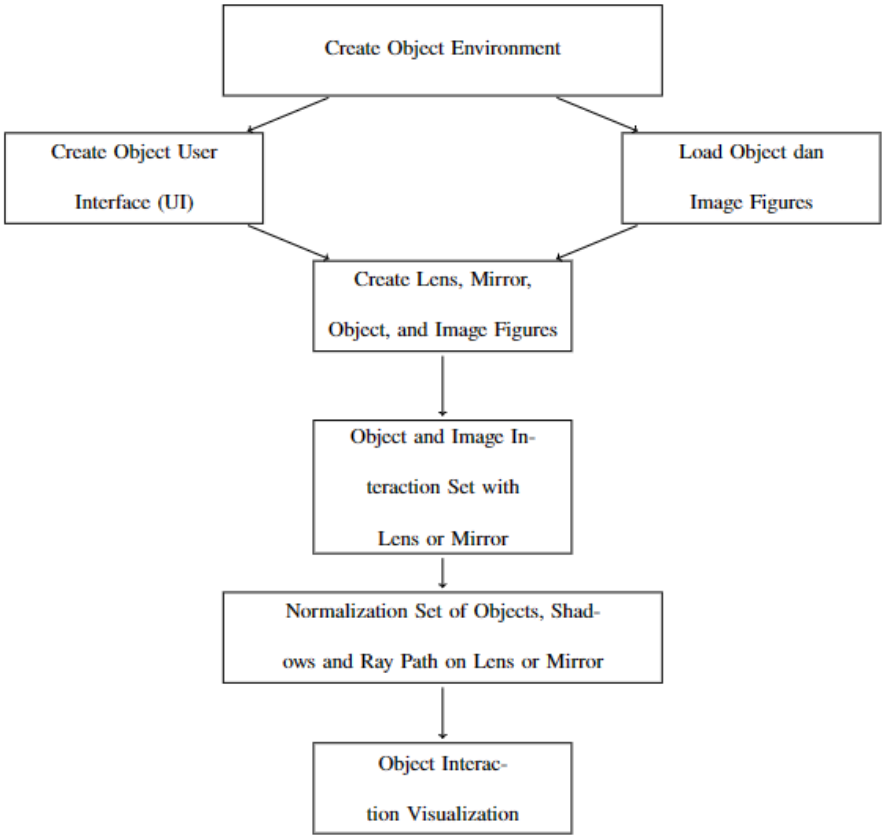


Figure 3. Lens and Mirror Simulation flowchart

from two flat mirrors that are adjacent to form a certain angle which later can be known the number of shadows formed. Simulations in the mirror section consist of three types of mirrors, namely flat, convex and concave mirrors with four types of objects in the form of apples, pencils, boxes, and triangles. The next material is lenses, which are presented in the form of text, learning videos, practice questions and simulations consisting of convex and concave lens simulations. For optical devices material, the material is presented in the form of text assisted by images. In this section of optical instrument material, there is a summary of material about light and optical devices. The last part of the presentation is a competency test containing 15 multiple choice questions. The "How to Use" section button contains instructions on how to use the learning media. Finally, the "About" section contains the bio of the interactive learning media developer.

The simulation contained in the interactive media is made using a software, namely p5.js. P5.js is a software based on the JavaScript programming language that has special uses to create an interactive media, using only the syntax or commands of the programming language. The simulation framework made refers to the flowchart shown in Fig. 3. The initial stage of the simulation framework is to create an environment object from the simulation, such as the simulation canvas. Then, the next is to create a user interface (UI) in the form of buttons used to place objects on the simulation canvas, such as objects and also lens or mirror objects. Then, a program is given that is useful for providing an interaction on the object so that it can be positioned according to the mirror plane or lens plane. Then, the shadow formation stage is obtained using the concept of ray paths or ray paths based on special rays on a mirror or lens, then the result of the intersection between the ray paths will be the benchmark for a shadow formed from an object. Of course, the object normalization stage is also carried out, where the normalization is carried out to obtain the theoretical distance of the object to the mirror or lens

and the theoretical distance of the object's shadow to the mirror or lens. The normalization is done because the simulation canvas in p5.js is in the form of pixels, so it must be normalized to get the length unit value in the form of *cm*. And the last step is the visualization of object interaction that can be seen through Fig. 4 which is the display of the simulation on the lens, which is made with p5.js. There is a gray screen or canvas, then the lens object, and the object that is used to simulate the shadow formation, which is a pencil. The shadow formation is obtained using the ray diagram principle.

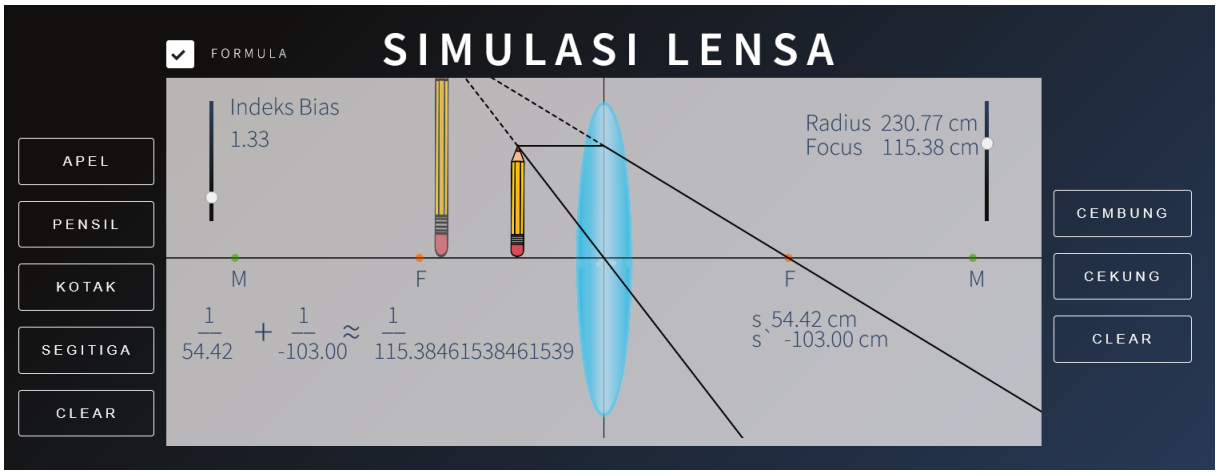
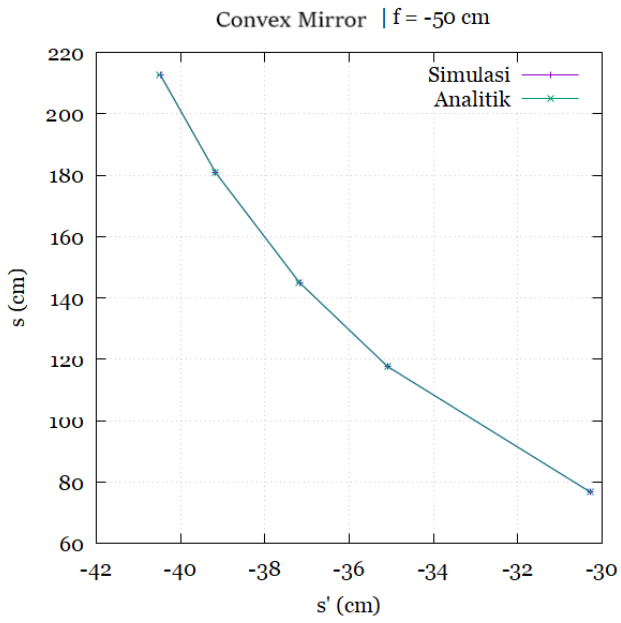


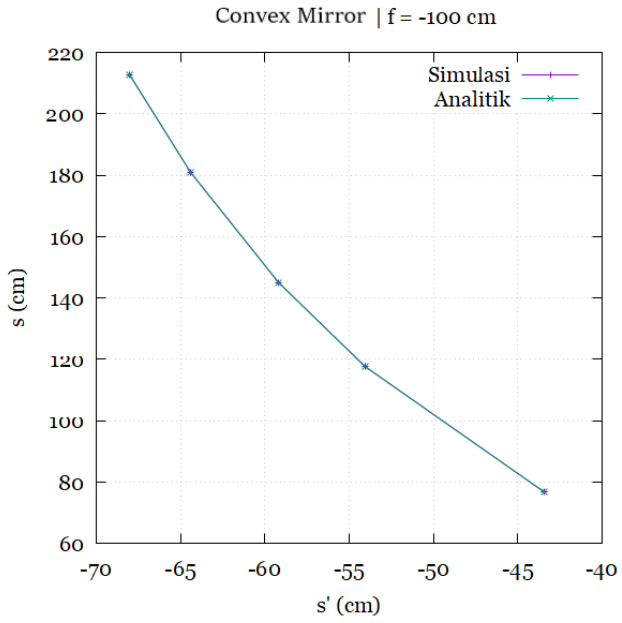
Figure 4. Lens Simulation

The ray diagram is triggered based on the theoretical ray diagram concept, and the intersection point between the ray lines is the height and position of the shadow formed. In the simulation, position normalization is also performed, where by default from p5.js, the coordinate points x=0 and y=0 or (0,0) are located at the top left corner of the canvas. The normalization is used to obtain a length measure in *cmm* for the line plane of the simulation, such as the focus distance to the center of the mirror or lens, the object distance, and the shadow distance to the center of the mirror or lens.

The main point of this interactive learning media is the self-generated simulation. In this interactive learning media, there are simulations for mirrors and lenses. The mirror simulation consists of flat, convex and concave mirrors while the lens simulation consists of convex and concave lenses. The objects in these simulations consist of apples, pencils, boxes and triangles. In the simulation, there are equations that show the focal point, object distance and shadow distance. After analytical calculations, it can be seen that the calculation results in the simulation are not much different from analytical calculations.



(a)



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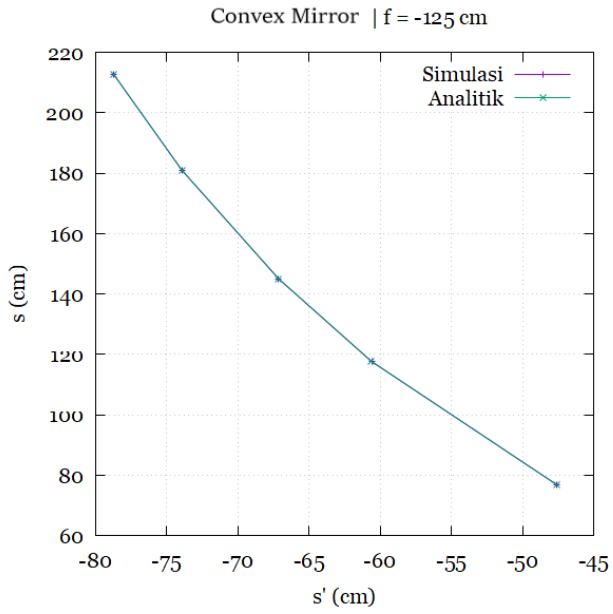

(c)

Figure 5. Comparison between analytic and simulation for convex mirror. (a) focal = -50 cm, (b) focal = -100 cm, focal = -125 cm

From the data and calculations, the coefficient correlation ranges are around 0,000427 - 0,021912; 0,003426 - 0.243858; 0,003298 - 0,082615; and 0,001004 - 0,183618 for convex mirror, concave mirror, convex lens and concave lens data respectively. Then the results of analytical calculations for each simulation case of convex mirror, concave mirror, convex lens, and concave lens, are presented in the form of graphs comparing analytical values with simulation values that have been made. Fig. 5 shows the comparison of analytical and simulation calculations for the reflecting mirror, for three different focal distance selections,

namely: -50 *cm*; -100 *cm*; -125 *cm*. In all three graphs, it can be seen that the comparison between the simulation calculation and the analytical calculation shows a fairly small error or difference, which can be interpreted that the simulation made in the interactive media is able to show a fairly high accuracy of the results.

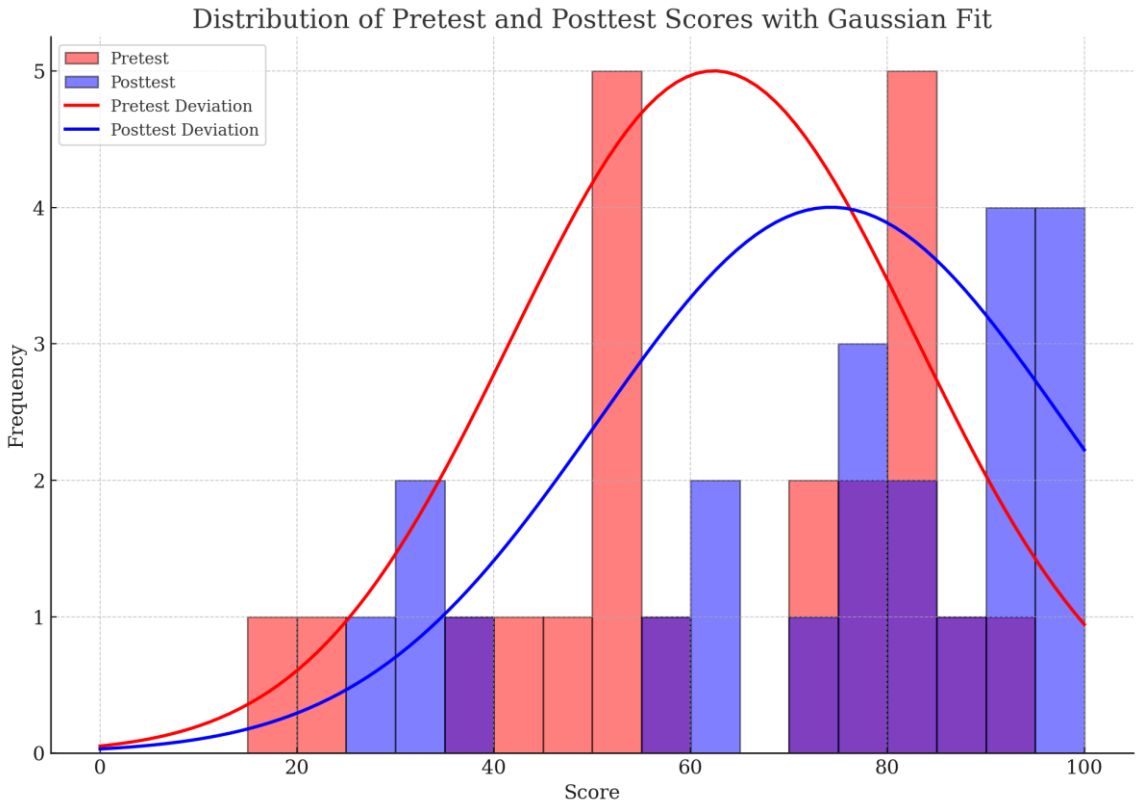

Figure 6. Pretest and Posttest Distribution

After comparing simulation calculations with analytics, the interactive learning media was tested on SMP Muhammadiyah 10 Bandung students and verified by Muhammadiyah 10 Bandung SMP science teachers. The test consisted of working on questionnaires and studying material with interactive learning media, the questionnaire in the test was divided into pretest, posttest and practicality test. Pretest and posttest were conducted in order to determine changes in student understanding before and after using interactive learning media, while the practicality test was conducted to determine student opinions about the interactive learning media. The student sample that was tested in this study was grade 9, the sampling was based on the fact that grade 9 had studied light and optical devices. Furthermore, teacher verification is carried out with teachers who observe the content of the learning media with several aspects of assessment such as the completeness of teaching materials, coverage of teaching materials, interactive presentation, teaching benefits, and implementation opportunities. The following is the result data from student testing and teacher verification of SMP Muhammadiyah 10 Bandung.

The Gaussian distribution is presented through the results of the distribution of students' pretests and posttests as in Fig. 6. The equation used to explain the distribution Gaussian:

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}(\frac{x-\mu}{\sigma})^2}$$

Based on the data obtained from the pretest and posttest scores, the μ value for the pretest is 62.36 and for the posttest is 74.27. The value of the average shows the peak of the distribution for each pretest and posttest distribution curve, so it can be seen that there was an

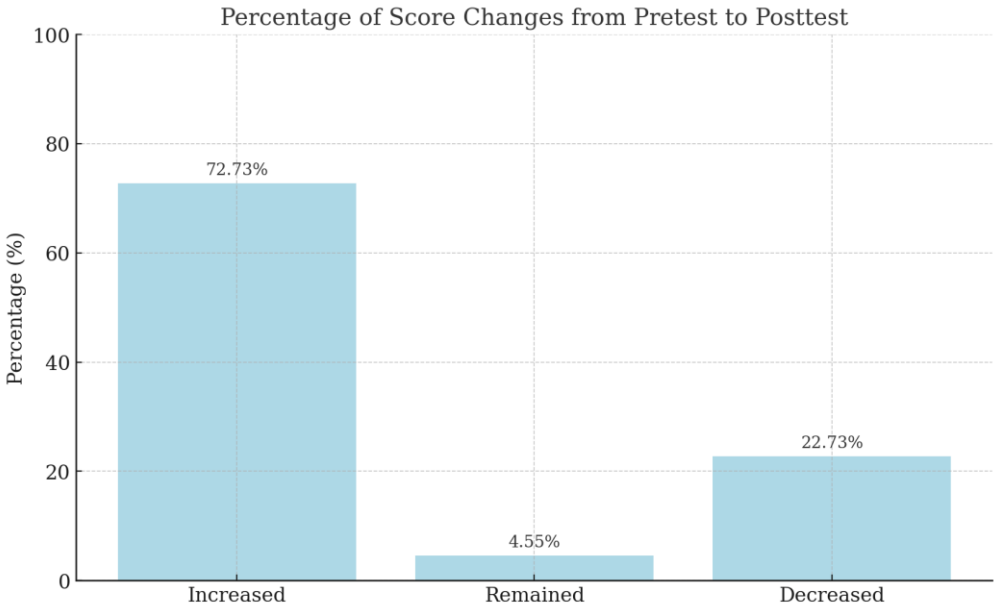

Figure 7. Percentage of Score Changes from Pretest to Posttest

increase in the posttest or assessment after the students took the test. It can be seen that there was an increase in the posttest or assessment after students learned the material using the interactive learning media. learn the material using interactive learning media.

Thus, as we see in Fig. 7, the histogram shows the percentage change in pretest and posttest scores that have been carried out by students. The percentage change in pretest and posttest scores is divided into three categories, namely "Increased", "Fixed", and "Decreased". For the "Increase" category, the percentage is quite high at 72.73%, which shows the significant development of students after taking the pretest and posttest, while for the "Fixed" category, the percentage is quite small at 4.55%, and for the "Reduced" category, the percentage is 22.73%. The results of this data are able to provide responses to the interactive learning media that has been made as a new place for students to understand and learn material easily and effectively.

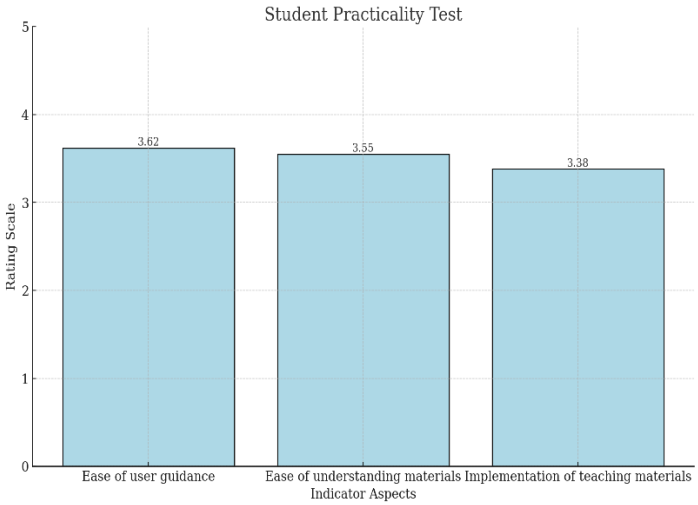

Figure 8. Practicality test result by students

Based on the results of Fig. 8, it can be seen that there is an increase in posttest or assessment after students learn the material using interactive learning media. The rating scale

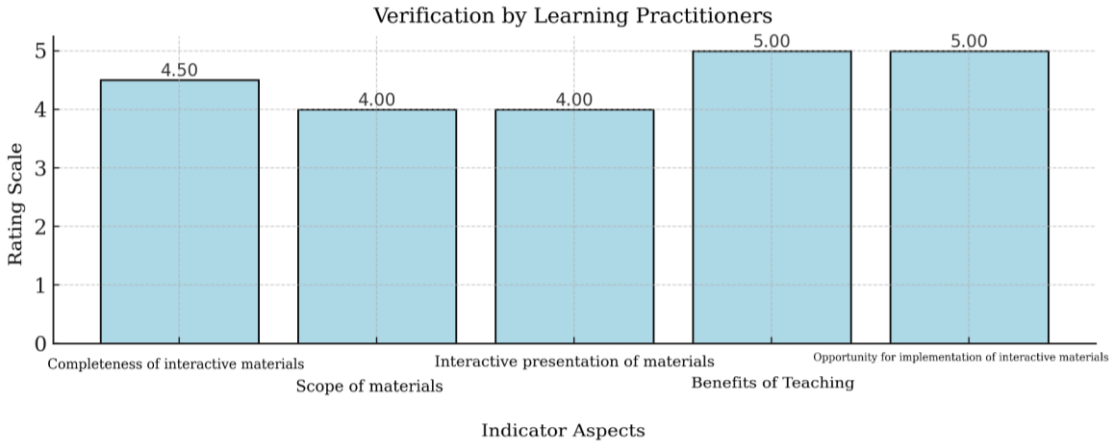

Figure 9. Learning practitioner verification result

determined to support the results of verification by students is as follows: 1. 1 - 1.8 is "Very Bad". 2. 1.81 - 2.6 is "Bad". 3. 2.61 - 3.4 is "Average". 4. 3.41 - 4.2 is "Practical". 5. 4.21 - 5 is "Very Practical". Furthermore, Fig. 7 shows the results of the practicality test by students. The assessment indicators are based on three aspects, namely the ease of user guidance, ease of understanding the material, and the application of teaching materials. The ease of user guidance gets an average of 3.62 which is included in the "Practical" category, the aspect of ease of understanding the material gets an average of 3.55 which is included in "Practical", as well as the aspect of the application of teaching materials with an average of 3.38. In testing the learning media, students try through smartphones so they cannot access the simulations provided.

Meanwhile, the rating scale determined to support the verification results by learning practitioners is as follows: 1. 1 - 1.8 is "Very Poor". 2. 1.8 - 2.6 is "Poor". 3. 2.61 - 3.4 is "Average" 4. 3.41 - 4.2 is "Good". 5. 4.21 - 5 is "Very Good". Then Fig. 9 shows the results of verification from learning practitioners. The learning practitioner in question is a science teacher at SMP Muhammadiyah 10 Bandung. The assessment aspects of the verification include the completeness of interactive teaching materials, interactive coverage of teaching materials, interactive presentation of teaching materials, interactive teaching benefits, and implementation opportunities for interactive teaching materials. If based on the completeness of teaching materials, this interactive learning media gets a score of 4.50 which is included in the "Very good" category. In this aspect of the assessment based on how complete the teaching materials or materials presented in interactive learning media. The coverage of teaching materials gets a score of 4.00 which is included in the "Good" category, the coverage of teaching materials here is the limit of the material presented. Then for the interactive presentation of teaching materials gets a score of 4.00 which is included in the "Good" category. Furthermore, the teaching benefits and implementation opportunities received a score of 5.00 which is included in the "Very Good" category. The completeness of teaching materials broadly consists of knowledge, skills, and attitudes that students must learn in order to achieve predetermined competency standards (Anggereni et al., 2021)..

CONCLUSION

Research with a topic entitled "Web-Based Interactive Learning Media Development using p5.js on Light and Optical Device Module for High School Competency" can provide several conclusions based on the objectives of this study, namely: - This research designs interactive learning media for the material "Light and Optical Devices" which contains a

simulation of mirror and lens experiments made using p5.js software. - This research has also carried out analytical calculations for mirror and lens equations, and made comparisons with the results of simulations made, then the difference or error value obtained between the analytical value and the simulation has a significantly small coefficient correlation which is around 0,000427 - 0,021912; 0,003426 - 0.243858; 0,003298 - 0,082615; and 0,001004 - 0,183618 for convex mirror, concave mirror, convex lens and concave lens data respectively. - This study also validated interactive learning media to students and learning practitioners at SMP 10 Muhammadiyah Bandung which gave results categorized into "Practical" by students, and "Very Good" by learning practitioners. Suggestions from this research that can be given by the author are, by developing the topic of interactive media material other than the topic "Light and Optics" which is certainly an alternative learning support for middle and high school students, as well as by developing other physics simulations that are implementable. Of course, by designing a simulation, it will make it easier to explore a representative material, especially in the field of physics.

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