Virtual Microscopic Simulation (VMS) Design on Light Waves: Interference and Diffraction

D Anggraini¹, F C Wibowo² and M Delina²
¹Physics Education Master Program, Universitas Negeri Jakarta, Jl. Rawamagun Muka, Rawamangun, 13220, Indonesia
²Department of Physics Education, Universitas Negeri Jakarta, Jl. Rawamagun Muka, Rawamangun, 13220, Indonesia
Email: dewi25308@gmail.com, fcwibowo@unj.ac.id, Mutia_Delina@unj.ac.id

Abstract. The properties of light waves are only looking indirectly through physic phenomena, such as interference and diffraction of light. This causes light waves to become of the physics materials that are difficult for students to understand. This study aims to produce a Virtual Microscopic Simulation (VMS) design on light wave material. The research method used in this research is research and development using the ADDIE development model. However, the ADDIE development model used is only to Design stage. The instrument used to measure the feasibility of VMS media is a validation test by media and materials experts. The results showed that characteristics of VMS design in light waves consist of two topics, namely interference and diffraction of light. VMS has a positive impact on students in the physics learning, especially about microscopic materials. VMS expected to effective in helping students to understand the light wave material, especially about the concept of interference and diffraction of light.

1. Introduction
Visible light is a form of electromagnetic radiation, so the light has properties like a wave. The properties of light waves are only looking indirectly through physic phenomena, such as interference and diffraction of light. In physics learning, often when studying the concept of interference and diffraction of light in the classroom, students directed to solve problems with the use of complicated math and then to prove for real carried out experiments of interference and diffraction light in the laboratory [1]. This causes most students have difficulty in learning the concept of interference and diffraction light correctly [2]. In addition, the student's greatest difficulty in understanding light waves lies in the fact that students are unable to interpret of interference and diffraction concept in terms of basic wave models as well as their lack of understanding de Broglie wavelengths [3]. Many students fail to observe important features of particular patterns and identify the differences among similar patterns [4]. Even students who have studied light waves at the introductory level and beyond are often unable to explain the patterns of interference and diffraction produced on the screen, whether in a single slit or double slit. Many don’t know whether to apply geometric optics or physical optics to certain situations and make it possible to improperly combine the elements of the two. Meanwhile, the symptoms of interference and diffraction of light are often met in everyday life, such as oil scattered on a paved road reflects the rainbow colours that seem after the rain. The colours seen in the oil are due to interference between the light reflected on the front surface and the thin back surface of the oil. If many sources of waves present in the oil result in diffraction [5]. In some other cases, most students have difficulty recognizing double slit interference.
patterns and diffraction lattice patterns of light [6]. Therefore, teachers and students must show attention to observing and distinguishing patterns of interference and diffraction in light waves.

Based on this description, needed approach that facilitates development of a relatively deep idea of light waves, where the tools used can visualize light waves in real [7]. One of the efforts to solve this problem is to develop new media that can describe and visualize the physical phenomenon of interference and diffraction light which are then integrated with existing theories. The right medium to help students in visualizing light waves is computer simulation.

Computer simulations usually model abstract concepts and involve mathematical models [8]. Computer simulation is a simulation run by a single computer used to show a behaviour of a system. The computer simulations developed are adapted to the characteristics of the system. Computer simulations are designed to be effective in conceptual change [9]. Computer simulations offer representations ideal, dynamics and visual of physical phenomena and experiments dangerous, expensive or unfit in school laboratory [10]. Computer simulations can be used to demonstrate or practice phenomena that are difficult to be shown in the classroom [11]. The advantage of simulation when compared to other media are simulations can present simplified external visualizations of phenomena that are not easily observed by students and direct them to think interconnection between theory and its visualization [12] [13].

Computer simulations commonly used in classroom learning are virtual simulations. Virtual simulation is a learning media that displays a physical model of an object or an abstract phenomenon. Virtual simulations available in physics learning are still limited to certain physics concepts such as force, Hooke's Law, Faraday's Law, heat transfer, dynamic electricity, transition phase, and sound waves. In the concept of light waves, simulations are already available for interference and diffraction of light topics across several platforms as in PhET simulation. Based on the results of the analysis of media availability, it was found that the available simulations only show the visualization of how the light source passing through the slit experiences interference and diffraction of properties, where these properties described by light and dark patterns captured on the screen. Available simulation media have not been able to visualize microscopically how the process of interference and diffraction of light occurs both in a single slit and double slits so that students are still quite difficult to recognize and distinguish interference patterns and light diffraction correctly. From these findings can give opportunity to conduct research by designing VMS on light wave topics. Advantages of using VMS by users can clearly visualize the abstract phenomena microscopically and manifestly; reduce the occurrence of misunderstanding; improve students' understanding; and build a view that more scientific [14] [15]. This study will discuss the design of VMS media, which has an overview of the process of interference, and diffraction of light microscopically and real.

2. Method

The method used in this research is the Research & Development method. Media development made reference to the ADDIE development model. However, the ADDIE development model only to the design stage. Analysis stage is a stage to know the needs of physics learning media in schools. The analysis includes literature studies in the form of journal analysis and availability of simulation media, needs student analysis, and needs teacher analysis. While the design stage is the stage that determines how a learning program designed according to the needs and goals of learning. The design includes the storyboard of Virtual Microscopic Simulation (VMS). The instrument used to measure the feasibility of VMS media is a media and material validation test by several experts. The scheme of ADDIE model development can see in Figure 1.
3. Results and Discussion

3.1 Main Menu
Virtual Microscopic Simulation (VMS) is a tool used to visually imitate an abstract phenomenon to make it look more real with the help of a computer. The design characteristics of VMS on light wave material consists of two topics, namely interference and diffraction of light. The design of the VMS on light wave material can be seen in Figure 2.

Figure 2 shows the main menu page on VMS, which contains the developer profile menu, double slit interference menu, a single slit diffraction menu, diffraction grating menu, previous button and exit button. Each interference and diffraction of light menu contain a simulation and an explanatory material of the simulation display.

3.2 Double Slit Interference
The simulation of double slit interference as shown in Figure 3.
Figure 3 shows a simulation of double slit interference selected by the user. On this screen there are several settings menus that can be changed according to the experiments by the user. The settings menu in this simulation consists of a wavelength setting button, a wide setting button between two slits, a screen to slit spacing setting button, a microscopic display button that serves to microscopically display the process of light interference in a double slit. In addition, if the user wants to return to the main menu, they can click the home button and to exit the simulation, the user can click the exit button. The microscopic simulation display of double-slit interference is illustrated in Figure 4.

The output in this simulation will present a display of the light propagation process that through two narrow slits to create a light/dark pattern captured on the screen. When a light/dark pattern captured on the screen, a display box will appear in the form of a graph of wave intensity and the distance between the light/dark lines to the central light.

3.3 Single Slit Diffraction

Light diffraction is the bending of light waves through a narrow slit. The simulation of single slit diffraction as shown in Figure 5.
Figure 5 shows a simulation of a single slit diffraction selected by the user. On this screen there are several settings menus that can change according to the experiments by the user. The settings menu in this simulation includes a wavelength setting button, a wide setting button between slits, a screen to slit distance setting button, a microscopic display button that serves to microscopic display the process of light diffraction performing at a single slit. If the user wants to return to the main menu can click the home button and to exit the simulation click the exit button. The microscopic simulation display of single-slit diffraction is illustrated in Figure 6.

The output in this simulation will present a display of the light propagation process that through a narrow slit resulting in a light/dark pattern captured on the screen. If a light/dark pattern is captured on the screen, a display box will appear in the form of a graph of wave intensity and the distance between the light/dark lines to the central light.

3.4 Diffraction grating

The simulation of diffraction grating as shown in Figure 7.
Figure 7 shows a simulation of the diffraction grating selected by the user. On this screen there are several settings menus that can change according to the experiments by users. The settings menu in this simulation consists of wavelength setting buttons, lots of grids setting button, the screen in a grid spacing setting button, a microscopic display button that serves to microscopic display the process of light diffraction occurrence on the grid. On the screen there is also a home button that serves to return to the main menu, and for users who want to exit the simulation can click the exit button. The microscopic simulation display of a diffraction grating is illustrated in Figure 8.

The output in this simulation will present a display of the light propagation process that through a grid, resulting in a light/dark pattern captured on the screen. If a light/dark pattern captured on the screen, a display box will appear in the form of a graph of wave intensity and the distance between the light/dark lines to the central light. The design characteristics of VMS on light wave material consists of two topics, namely interference and diffraction of light. The result of VMS design will produce VMS media used by students to see, recognize, and understand how the process of interference and diffraction of light so that patterns of interference and diffraction of light form in the form of light and dark lines. The advantages of the developed VMS product are (1) the VMS visualizes microscopically how light propagates so that light to have light interference and diffraction properties, (2) VMS displays the relationship between the distance between the slits and the intensity of light waves. This helps students to know that the smaller the distance between the slits, the greater intensity of the waves. (3) VMS displays how the relationship between wavelength and intensity of light waves. This helps students to know that the greater the wavelength, the greater intensity of the wave. (4) VMS is easy to access and use anytime anywhere. VMS has a positive impact on students in the study of physics, especially of...
microscopic material. With the development of VMS expected to effectively help students to reduce misconceptions and improve their understanding in studying light wave material, especially on the topic of interference and diffraction of light.

4. Conclusion

Virtual Microscopic Simulation (VMS) is a tool used to visually imitate an abstract phenomenon to make it look more real with the help of a computer. The design characteristics of VMS on light wave material consists of two topics, namely interference and diffraction of light. VMS has a positive impact on students in the study of physics, especially on microscopic material. With the development of VMS expected to effectively help students to understand the light wave material, especially about the concept of interference and diffraction of light.

References

[1] L Maurer 2013 Simulating interference and diffraction in instructional laboratories Phys. Educ 48 227
[2] V Mesic, K Neumann, I Aviani, E Hasovic, W J Boone, N Erceg, V Grubelnik, A Sušac, D S Glamočić, M Karuza, A Vidak, A Alihodžić, R Repnik 2019 Measuring students’ conceptual understanding of wave optics: A Rasch modeling approach Phys. Rev. Phys. Educ. Res 15 010115
[3] S Vokos, P S Shaffer, B S Ambrose, L C McDermott Y 2000 Student understanding of the wave nature of matter: Diffraction and interference of particles American Journal of Physics 68 S42
[4] A Susac, M Planinic, A Bubic, K Jelicic, L Ivanjek, K M Cvenic, M Palmovic 2021 Effect of Students’ investigative experiments on students’ recognition of interference and diffraction patterns: An eye-tracking study Phys. Rev. Phys. Educ. Res 17 010110
[5] H D Young and R A Freedman 2001 Fisika Universitas Edisi Kesepuluh Bandung: Erlangga
[6] A Susac, M Planinic, A Bubic, L Ivanjek and M Palmovic 2020 Student recognition of interference and diffraction patterns: An eye-tracking study Phys. Rev. Phys. Educ. Res 16 020133
[7] V Mesic, E Hajder, K Neumann and N Erceg 2016 Comparing different approaches to visualizing light waves: An experimental study on teaching wave optics Phys. Rev. Phys. Educ. Res 12 010135
[8] D R Darman, F C Wibowo, A Suhandi, W Setiawan, H Abizar, S Nurhaji, S Nulhakim, L Nulhakim and A Istandaru 2019 Virtual media simulation technology on mathematical representation of sound waves Journal of Physics: Conf. Series 1188 012092
[9] K C Trundle and R L Bell 2010 The use of a computer simulation to promote conceptual change: A quasi-experimental study Computers and Education 54 1078
[10] C Sarabando, J P Cravino and A A Soares 2014 Contribution of a computer simulation to students’ learning of the physics concepts of weight and mass Procedia Technology 13 112
[11] G Triyani, A Danawan, I Suyana, I Kaniawati 2019 An investigation of students’ misconceptions about momentum and impulse through interactive conceptual Instruction (ICI) with computer simulation Journal of Physics: Conf. Series 1280 052008
[12] A Budi, D Muliyati 2018 Discovering and understanding the vector field using simulation in android app Journal of Physics: Conf. Series 1013 012062
[13] S Moser, J Zumbach, I Deibl 2017 The effect of metacognitive training and prompting on learning success in simulation-based physics learning Science Education 101 944
[14] F C Wibowo, A Suhandi, D Rusdiana, Y Ruhiat, D R Darman, A Samsudin 2017 Effectiveness of Microscopic Virtual Simulation (MVS) for conceptualizing students’ conceptions on phase transitions American Scientific Publishers 23 839-843
[15] F C Wibowo, B H Iswanto 2019 Designing MOOCS with Virtual Microscopic Simulation (VMS) for increasing of student's level of understanding Journal of Physics: Conference Series 1402 066094