Augmented Reality Geometrical Optics (AR-GiOs) for Physics Learning in High Schools

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Abstract. This study aims to produce "Augmented Reality Geometrical Optics (AR-GiOs)" as a medium for physics learning for geometrical optics in high school. The method used in this study is the Research and Development method with the ADDIE model (Analyze, Design, Develop, Implement, and Evaluate). AR-GiOs was developed to facilitate students in learning the concept of image formation and image properties of mirrors and lenses. AR-GiOs can display four 3D simulations, including 3D simulations of the image formation process by a concave mirror, a convex mirror, a concave lens, and a convex lens. In addition to AR, in this study, a worksheet was also developed to guide student learning activities and valuable as a marker. The results of product validation covering the material and media aspects got a very good average score (84% and 90%). Based on the results of the expert validation test, it can be concluded that AR-GiOs is suitable for use as a medium for learning physics in high school.

1. Introduction

Optical image formation is one of the abstract physics materials, so it requires critical thinking skills to understand the theories and compare them with symptoms in everyday life [1]. Most students have misconceptions about analyzing image formation by mirrors and optical devices [2]. Students also have difficulty understanding the concept of image formation, such as real images, virtual images, and magnification [3]. Other researchers also stated that students had difficulty in determining the location of the image, the type of image (real or virtual) [4]. Some of the factors that can lead to student misunderstandings include students’ daily experiences, language used, teachers, and textbooks [3].

Mobile technology can be an interesting learning medium that helps students overcome conceptual difficulties and learn more enthusiastically [5, 6]. The initiatives which transform mobile devices into tools for learning, and which support equitable opportunities for students who cannot afford them, generally provide affordable solutions to educational challenges [7]. Augmented Reality (AR) is one of the solutions needed to be present in learning activities. Augmented Reality (AR) can synergize with smartphones so that it becomes an effective, efficient, and useful learning medium in the learning environment. Augmented Reality (AR) improves digital-age literacy, creative thinking, communication, collaboration, and problem-solving ability, which constitute the so-called twenty-first-century skills, necessary to transform information rather than just receive it [8]. Especially in the field of physics, it can provide a more realistic expression through various physics-based simulations that allow students to achieve high achievements [9]. Augmented Reality (AR) has many advantages for learning, including concretizing abstract concepts [10, 11], increasing mastery of concepts [10, 11, 12, 13, 14, 15], and improving critical thinking skills [16].

Previous research has proposed the use of Augmented Reality 3D techniques for physics experiments, in particular, to produce a convex lens image formation, experimental device integrated
with Augmented Reality (AR) to stimulate student interest in learning and increase activity levels [17]. However, this study only produced experimental devices for the convex lens. Other research has also developed an Augmented Reality (AR) based magnetic field learning application that can emphasize natural interactions. The weakness of this application is that the system is not always stable and the resulting animations overlap [18]. Other research has also produced MagAR, a magnetism teaching material using augmented reality and sensing technology [19]. However, these two studies did not produce Augmented Reality for geometric optical materials.

Several previous studies have produced Augmented Reality for Physics learning media but have not provided a solution for students' problems, specifically the process of forming images on geometric optical material. So that the researchers aim to produce "Augmented Reality Geometrical Optics (AR-GiOs)" as a medium for learning physics in high school on the subject of geometric optical image formation.

2. Methods

This research used research and development method with the ADDIE model. The ADDIE model consists of five stages, including Analyze, Design, Develop, Implement, and Evaluate [20]. However, this research only reached the third stage of the ADDIE model. The analysis was conducted to determine the needs of learning Physics in schools. The analysis carried out includes literature study, analysis of student needs, and analysis of teacher needs. Design is the creation of storyboards for AR-GiOs media. At the development stage, AR-GiOs application development and student worksheets were carried out. The software used to develop AR-GiOs is Blender, Unity 3D, and Vuforia. Meanwhile, student worksheets were created using Microsoft Word and Paint 3D.

3. Result and Discussion

3.1. AR-GiOs

AR-GiOs facilitates students in learning the concept of image formation and image properties by mirrors and lenses. AR-GiOs aims to visualize abstract concepts in the formation of images completely and well for students. In addition, AR-GiOs's ability to display three-dimensional objects will improve the quality of learning.

AR-GiOs can display four 3D simulations, including 3D simulations of the image formation process by a concave mirror, convex mirror, concave lens, and convex lens. The user can change the object distance and object height values in the 3D simulation so that the focal distance, image position, image height, and magnification values will be obtained. The object used in the 3D simulation is a flashlight with the GO logo. The orange lines in the figure show special rays.

![Figure 1. The process of forming an image by a concave mirror.](image1)

![Figure 2. Image of an object by a concave mirror.](image2)

Figure 1 shows a 3D simulation of the image formation process by a concave mirror. Figure 2 shows the results of the image of an object by a concave mirror. In picture 2, objects are 25.42 cm from the mirror, then the image of the object is 16.49 cm. So based on these experiments, the image of
the object is reduced, real, and inverted. If the object is placed in front of the focus then the image of
the object will be enlarged, virtual, upright. If an object is placed between the focus and the radius of
curvature of a concave mirror, the image of the object will be enlarged, real, and inverted [21].

Figure 3. The process of forming an image of a convex mirror.

Figure 4. Image of an object by a convex mirror.

Figure 5 shows a 3D simulation of the image formation process by a convex mirror. Figure 4 shows
the results of the image of an object by a concave mirror. In figure 4, objects are 7.5 cm from the
mirror, then the image of the object is -4.29 cm. So based on these experiments, the image of the
object is virtual, upright, and reduced. When the user changes the position of objects in a 3D
simulation of a convex mirror, the image will always be behind the mirror, so that the disposition of
the image formed by the convex mirror is always virtual, upright, and reduced [21].

Figure 5. The process of forming an image by a concave lens.

Figure 6. Image of an object by a concave lens.

Figure 5 shows a 3D simulation of the image formation process by a concave lens. Figure 6 shows
the image of an object by a concave lens. In figure 6 objects are 7.5 cm from the lens, then the image
of the object is -4.29 cm. So that based on these experiments, the properties of the image formed are
virtual, upright, and reduced. The disposition of the image formed by a concave lens is always virtual,
upright, and reduced [21].
Figure 7. The process of forming an image by a convex lens.  

Figure 8. Image of an object by a convex lens.

Figure 7 shows a 3D simulation of the image formation process by a convex lens. Figure 8 shows the results of the image of an object by a convex lens. In figure 8 objects are 17.28 cm from the lens, then the image of the object is 23.73 cm. So based on these experiments, the image of the object is enlarged, real, and inverted. If the object is placed in front of the focus, the image of the object will be enlarged, virtual, and upright. If the object is placed behind the radius of curvature of a convex lens, the image of the object will be enlarged, real, and inverted [21].

3.2. Student Worksheet

In making learning activities complete, student worksheets are developed to guide student learning activities. Student worksheets also serve as markers. Student worksheets are integrated into the AR-GiOs application so that before starting learning students can download and print student worksheets. AR-GiOs student worksheet components, including cover pages, introduction, table of contents, information on “AR-GiOs Worksheet”, instructions for use, AR-GiOs Markers, core competencies, basic competencies and indicators, experimental activities, and bibliography.

The student worksheet contains four experimental activities, including the experimental activity of forming an image on a concave mirror, a convex mirror, a concave lens, and a convex lens. Experimental activities contain (1) experimental objectives, (2) basic theory, (3) initial questions, (4) tools and materials, (5) experimental steps, (6) observation tables, (7) data analysis and discussion, and (8) conclusion.
Figure 9 shows the front page of the experiment and the objectives of the experiment. The purpose of the experiment informs the knowledge and skills that students will acquire after learning. Students can identify optical concepts from the basic theory in Figure 10. Before starting the experiment, students answer initial questions to determine initial abilities. Virtual tools and materials used in virtual experiments include concave mirrors, convex mirrors, concave lenses, convex lenses, flashlights with the GO logo, and experimental tables.

Students conduct experiments following the experimental steps in Figure 11. AR-GiOs uses 4 markers in figure 11, including convex mirror marker, concave mirror marker, convex lens marker, and concave lens marker. When the user selects the start, learning menu, then scans one of the markers. Then a 3D simulation will appear on the cell phone screen. The AR-GiOs application will be able to display 3D animation. Students write down experimental data in the observation table that has been prepared in Figure 12. The data obtained include focus, object distance, object image distance, object height, image height, and magnification. After the experimental data is obtained, students are expected to conduct data analysis and discussion. The last stage of the experiment is the students write the conclusion of the experiment.

3.3. Validation Test Results

AR-GiOs has been tested for validity by media experts and material experts. The following are the results of AR validation and student worksheets. As shown in Table 1, the results of the validation of media experts in this research product obtained an average value of 90%, which was categorized as very well. The results of the validation of material experts get an average score of 84%, which was categorized as very well. So it can be concluded that the AR-GiOs meets the requirements and is feasible as a medium for Physics learning on geometric optics for high school students.
Table 1. Validation results

| Aspects Measured                          | Presentation Scale | Interpretation |
|-------------------------------------------|--------------------|----------------|
| **Media Expert Validation**               |                    |                |
| Effectiveness of AR                       | 87%                | Very Good      |
| Efficiency of AR                          | 92%                | Very Good      |
| Satisfaction of AR                        | 91%                | Very Good      |
| Cover Layout of Worksheet                 | 87%                | Very Good      |
| Component of the student worksheet        | 90%                | Very Good      |
| Content of the student worksheet          | 94%                | Very Good      |
| Average of all aspects                    | 90%                | Very Good      |
| **Material Expert Validation**            |                    |                |
| 3D Simulation Concept                     | 90%                | Very Good      |
| Material Content of Worksheet             | 83%                | Very Good      |
| Writing Language of Worksheet             | 80%                | Good           |
| Average of all aspects                    | 84%                | Very Good      |

3.4. Discussion

Based on the results of the validation that has been done by media experts and material experts, it was found that "Augmented Reality Geometrical Optics (AR-GiOs)" has met the requirements and is feasible as a learning medium for the physics of geometric optical material on the concept of forming an image for class XI SMA. AR-GiOs solves the problems experienced by students, including: (1) the process of forming images, (2) the nature of the image from the image formed, and (3) the position of the image from the image formation on mirrors and lenses. AR-GiOs can visualize and concretize abstract concepts of image formation processes on mirrors and lenses, this is following the results of previous studies [9], [10], [11]. In addition, the ability of AR-GiOs that can display three-dimensional objects can improve the quality of learning, this is following the results of previous studies [8], [9].

AR-GiOs has overcome the limitations of previous studies, only produced experimental devices with convex lenses [17]. In addition, the experimental device developed has not discussed the formation of virtual and real images. AR-GiOs succeeded in visualizing the image formation process by a concave mirror, concave mirror, concave lens, and convex lens. In addition to this, users can vary the distance of objects and the height of objects in the 3D simulation. So users will get data, including focus distance, shadow position, image height, and magnification. AR-GiOs has succeeded in providing a satisfying experience and interaction satisfaction to students.

4. Conclusion

AR-GiOs has succeeded in simulating the image formation process in a concave mirror, convex mirror, concave lens, and convex lens. AR-GiOs can concretize abstract concepts in the process of forming real and virtual images. By using 3-dimensional visualization, AR-GiOs can provide a more realistic expression of the abstract shadow formation process. AR-GiOs can facilitate students in learning the concept of image formation and image properties of mirrors and lenses. Augmented Reality Geometrical Optics (AR-GiOs) has been worthy as a medium for learning physics on geometric optical material.

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