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Optimalization Interactive Book Augmented Reality (IBAR) for Lesson on Student STEM for Improving 21st-Century Skills (21-CS)

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Abstract

Physics specifically studies natural phenomena or matter in the scope of space and time. Natural phenomena are formed when there is an interaction between matter and energy. These interactions are mostly physical principles based on Mechanics, Electricity, Magnetism, Thermodynamics and Optics. It is often difficult for students to understand concepts because they cannot visualize these phenomena, thus exacerbating the students' lack of interest in learning STEM. Augmented reality (AR) is effective in showing the visualization and interaction of three-dimensional virtual objects like real so that it can facilitate the learning experience. This study aims to optimize the Interactive Book Augmented Reality (IBAR) for Lesson on Student STEM to improve 21st-Century Skills (21-CS) on the concept of optical geometry. Experimental research was conducted to determine the impact of the IBAR intervention on 21-CS consisting of Critical Thinking, Collaboration, Communication, and Creativity. The study was conducted on 90 physics education students, who were divided into two groups, the IBAR teaching group (N=45) and the conventional teaching group (N=45). The IBAR teaching group uses STEM-based learning with the help of IBAR while the conventional teaching group uses STEM-based learning without using IBAR. The results showed that the STEM-based learning environment assisted by IBAR had a significant positive impact on students' Critical Thinking, Collaboration, Communication, and Creativity compared to the STEM teaching group without using IBAR. The IBAR experience helps students visualize abstract concepts of Physics and if microscopic phenomena can be understood by students, then macroscopic phenomena will also be easy to understand.

Keywords: Interactive Book Augmented Reality (IBAR); Lesson on Student, STEM, 21st-Century Skills (21-CS).

1. Introduction

The universe becomes an object that is very important in human life because it is a part of a complete system that cannot be separated from human life. Humans as one of the living beings who inhabit the universe should learn and know the various secrets of nature (Frantzeskaki, 2019). By understanding the universe, humans will find it easier to navigate their lives and more easily overcome the problems they face in their lives. New methods and tools are constantly being sought to increase and increase student interest and improve the learning process to prepare for debriefing for future generations (Karaseva, et al., 2017)

The last few decades education has a very important role in preparing future generations to face the problems in life. The most basic problems are the demands of globalization and the demands for competence in the 21st Century. This competency is to be able to solve various problems in the complex social, economic, and environmental fields. Students should be provided with and can reflect on their ideas, hone their analytical skills, strengthen critical and creative thinking capacities, and demonstrate initiative (Wechsler, et al., 2017). Important collaboration skills are trained to hone students to work as a team, work effectively and respectfully in teams to achieve common goals and assume shared responsibility for completing tasks (Gonzales, 2020). In addition, communication skills are also very important to support the world of work (Lavi, et al., 2021). These 21st century skills are essential and vital to success in challenging and disruptive work and life (Carayannis, et al., 2021). Critical thinking skills are a super skill in the 21st century, "because they allow students to think deeply and solve unfamiliar problems in different ways. Critical thinking skills equip graduates with "skills that make them productive, effective at work and responsible." responsibility, and solving problems in a sensitive and caring way with other people, society, and the environment (Kivunja, 2015d).Critical thinking skills are important when they state that critical thinking skills support students to see problems in new ways and connect learning across subjects & disciplines Teaching critical thinking is important for all students in all subjects (Forawi, 2016).

Education must prepare forms of learning in the digital era and pedagogy that supports students in acquiring new competencies and skills to overcome the challenges of the 21st century (Caena, et. Al., 2019). The contribution of ICT will enable a more student-cantered approach, enabling personalized learning but will be complemented by informal and virtual opportunities (Sakine, et al., 2017). The use of mobile technology has the potential to increase student interest in learning. Mobile technology can be an interesting learning media that helps students overcome conceptual difficulties and learn more enthusiastically (Vieyra & Vieyra, 2014); (González, et al., 2015). Initiatives to turn mobile devices into media for learning will support equal opportunities in learning for disadvantaged students, as well as provide affordable solutions to educational challenges. However, the key is to see technology not as a single solution, but as within a culture of learning and collaboration (Marsick, et al., 2019). Virtual media can concretize microscopic material that can be used as a learning tool that is cheaper, easier, general, varied and fun in learning physics.

Physics is a part of Natural Sciences specifically studying natural phenomena that are not living or matter in the scope of space and time. Natural phenomena are formed when there is an interaction between matter and energy (Seadawy, 2017). So, physics is the study of matter, energy, and the interactions between them (D'Oca, et al., 2017). For example, in everyday life there is a phenomenon observed, namely the increase in the temperature of a substance when heated. This event is an interaction between substances and heat energy which influences increasing the temperature of the substance. The results of empirical investigations show that there are several factors that affect the high or low temperature increase of a substance when heated, including the mass of the substance, the specific heat of the substance, and the amount of heat given. Macroscopically this situation can be understood because it is based on the results of observations of measurable quantities. When there is a question why the mass of the substance, the specific heat of the substance, and the amount of heat given affect the increase in the temperature of the object when heated, the data from these observations cannot provide an adequate explanation because what is being studied is objects at the macroscopic level (Wibowo, et al., 2021). To be able to answer the questions above, a more basic study is needed to the microscopic level of objects. “The microscopic system is able to easily help macroscopic systems” (Chung, et al., 2020).

Conventional teaching is a process for students to gain knowledge through reading and memorization techniques and the teacher being the main character in learning. Conventional learning methods are usually carried out with the help of text, video, pen, paper, and two-dimensional (2D) images where learning practices that show real phenomena have not been trained, besides that 3D content experiences have not been facilitated in conventional learning (Faridi, et al., 2020). Based on recent research studies that 3D animated content provides a more immersive experience to students. Changes in teaching styles using games, digital platforms, and modern simulations are more beneficial for students because they increase interest and motivation during learning activities (Avilés, et al., 2019). One of the technologies capable of simulating 3 dimensions is Augmented Reality (AR). AR is an innovative technology for education in the era of industrial revolution (Papanastasiou, et al., 2018). AR is a technique of rendering virtual objects on real images captured by cameras and has the advantage of providing a different sense of reality from virtual reality (Thees, et al., 2020). Especially in the field of physics can provide a more realistic expression through various physics-based simulations that allow students to achieve high achievements (Cai, et al., 2017). AR technology can improve digital literacy, creative thinking, communication, collaboration, and problem-solving abilities, which are 21st century skills, which are needed to transform information rather than simply receive it (Cai, et al., 2020). AR has many advantages for learning, including facilitating learning (Akcayir, et al., 2017); (Abdusselam & Karal, 2020), concretize abstract concepts (Radu & Schneider, 2019), increase mastery of concepts (Lin, et al., 2020); (Fidan & Tuncel, 2019), improve laboratory skills (Akcayir, et al., 2017), improve problem solving (Guntur, et al., 2019), and improve critical thinking skills (Faridi, et al., 2020). Based on recent studies, AR can provide an engaging and interactive learning experience. AR creates the real world with virtual components, thereby enhancing the student learning experience by placing graphics, video, text, and audio in real-world scenarios. This process makes the learning process more real and practical, even for abstract content.

Many other researchers have also developed AR devices and researched their effects in learning Physics and have produced AR-based magnetic field learning applications that are able to emphasize natural interactions. Then an exploration was carried out to determine the effect of the application on natural interactions in physics learning and deep understanding compared to traditional learning tools (Cai S. et al., 2017); (Abdusselam & Karal, 2020), and (Fidan & Tuncel, 2019). The analysis of the results shows that the application can improve learning attitudes and learning outcomes. The weakness of this application is that the system is not always stable, the animations produced overlap each other. Other researchers, Abdusselam & Karal produced MagAR, a magnetism teaching material using augmented reality and sensing technology. Then conducted an exploration of its effect on academic achievement and student learning processes, and to identify students' views on augmented reality. Furthermore, Fidan and Tuncel produced an AR application called FenAR and explored the effect of Augmented Reality (AR)-assisted Problem Based Learning (PBL), namely FenAR on learning achievement and attitudes towards physics subjects.

AR is a popular technology that has been the focus of educational research over the last few decades (Akçayır & Akçayır, 2017; Delgado-Kloos, 2018). Prospects of using the augmented reality application in STEM-based Mathematics teaching (Kramarenko, et al., 2020). STEM education is one area where AR can be used effectively (Sırakaya, 2020). STEM education trains readiness in dealing with the real world to be able to coexist in complex multidimensional and multidimensional problems (Pimthong & Williams, 2018). Therefore, STEM education is offered in many countries to help people understand STEM and use it in their lives. STEM education enables people to achieve educational goals by preparing them for everyday life and working life (Pimthong & Williams, 2018). STEM education is an approach in which students participate in engineering design or research and achieve meaningful learning experiences through the integration of science, technology, and mathematics (li et al., 2020). STEM education is a meta-discipline defined as the creation of a whole new discipline based on the integration of information from other disciplines (Margot, & Kettler 2019).

Optical Concepts is one of the materials in physics learning that is abstract, so it requires high thinking skills to understand theories and compare them with symptoms in everyday life (Chang, et al., 2018). Several researchers also reported their research results related to optical learning as found in the literature that most students had misconceptions in analyzing image formation by mirrors and optical devices (Kaniawati, et al., 2020) conveyed. Other researchers (Widiyatmoko & Shimizu, 2018) present data showing that students have difficulty understanding the concept of image formation and the focal length of the lens in a mirror. In addition, students also have difficulty understanding the concept of image formation on optical devices, such as real images, virtual images, and magnification. They added that several factors that could contribute to student misunderstandings include students' daily experiences, the language used, teachers and textbooks. Another report concluded that students had difficulty determining the location of the image, the type of real or virtual image, or the orientation of the image for a particular object located at a certain position relative to an optical element, such as a mirror or lens (Gurel, et al., 2016). Thus, this research focuses on Optimizing Interactive Book Augmented Reality (IBAR) for Lesson on Student STEM for Improving 21st-Century Skills (21-CS).

2. Methodology

2.1. Participants

Students with educational background in physics were selected as the research sample. A total of 90 physics education students participated in this study. All students have no or very little knowledge of IBAR technology because they are still first year Class students. Table 1 presents the details of the participants in the study. To avoid other influences, the same lecturer taught the class for both groups.

Table 1. Details of STEM and IBAR Implementation Participants

Gender	Teaching STEM with IBAR Experimental Group	Teaching STEM conventional Group
Female	35	37
Male	10	8
Total	45	45

Based on Table 1, it was obtained that the number of participants in this study was 90 students. In the Experimental Group, learning was carried out using STEM Teaching with IBAR with 35 female students and 10 male students. In the conventional group, learning was carried out using STEM Teaching without IBAR with 37 female students and 8 male students.

2.2. Material

The implementation of IBAR is carried out in STEM-based learning which will provide knowledge of optical concepts in an interactive 3-dimensional form such as Light Reflection on a Concave Mirror, Light Reflection on a Convex Mirror, and Light Refraction on a Concave Lens, Light Refraction on a Convex Lens This IBAR consists of 4 (four) interactive 3D, Figure 1 IBAR Flowchart in defining the display of action settings performed on the gameplay of the IBAR system. Figure 1 shows the IBAR visualization of the starting stage after the camera detects the marker in the form of a marker and students can visualize the IBAR of a particular learning activity depending on the type of marker. Each activity in learning has different markers.

Figure 1. IBAR-assisted STEM Flowchart for physics learning

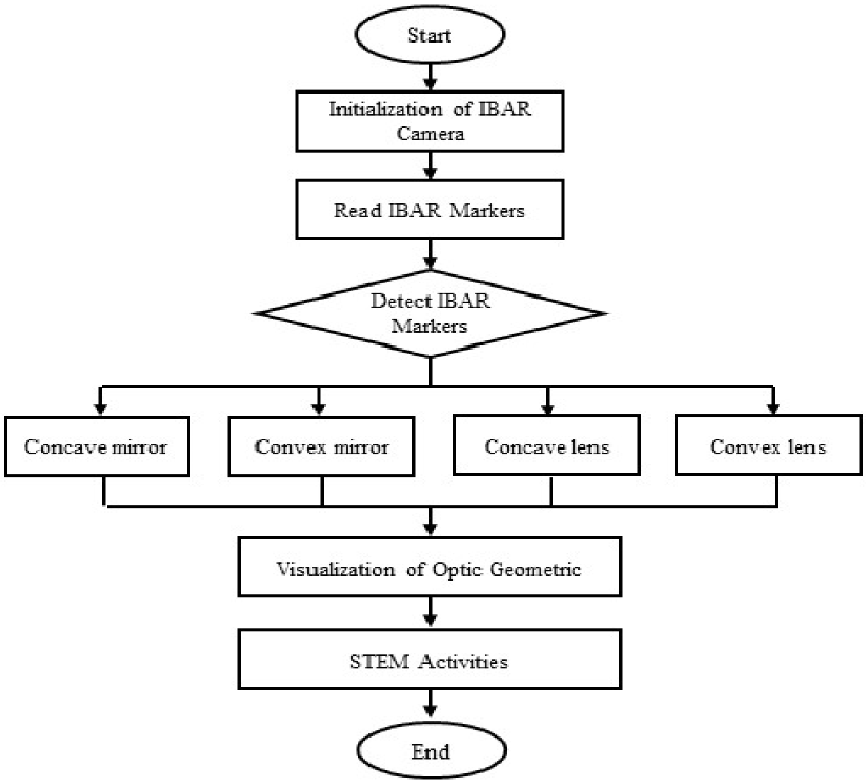
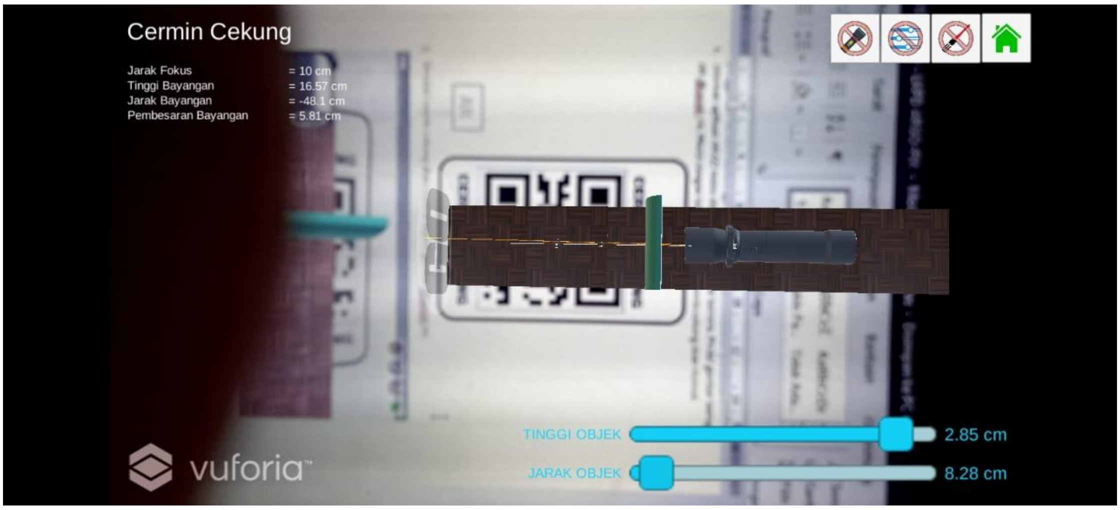


Figure 1 IBAR of students can visualize the Reflection of Light on a Concave Mirror in 3D. The light source from a flashlight illuminates a concave mirror and the light is run, with a focal length of 10 cm, the beam distance is -48.1. If the object (A) is placed between the focal point (F) and the point of intersection of the principal axis with a concave mirror (O), the formation of its image (A') is shown in Figure 1 and the point of intersection of the principal axis with the concave mirror (O), the image (A') formed is virtual, erect and enlarged. Put your image behind the mirror.

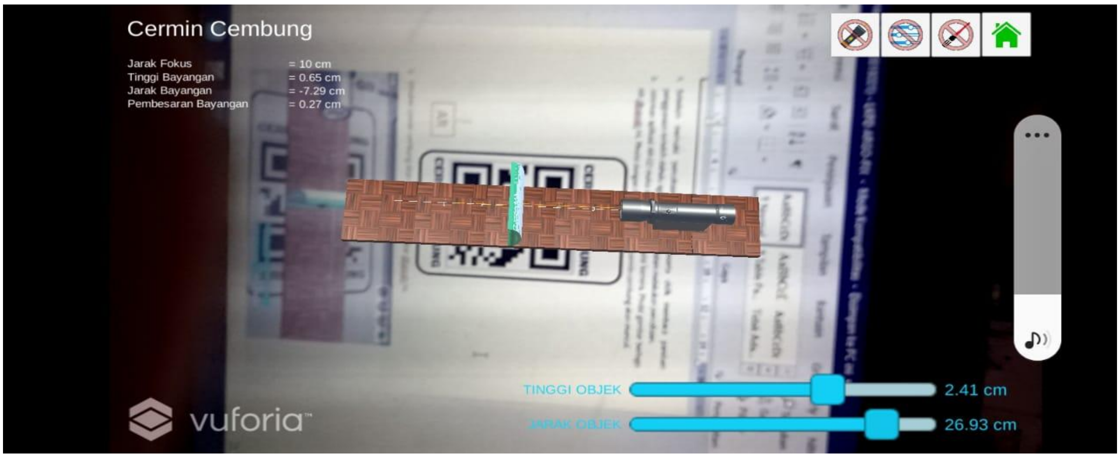
Figure 2. IBAR Display for Reflection of Light on a Concave Mirror



Reflection of light in a concave mirror can be adjusted to the height of the object and the distance of the object to make it easier for students to absorb changes in the shape of the image. This IBAR facilitates students to reflect concave mirrors with some image formation. The formation of this image occurs when the object is placed between the centre of curvature of the mirror (P) and the focal point of the mirror (F). The shadow formation is shown as in the Figure below. From the figure if an object is placed between the centre of curvature (P) and the focal point (F), the image formed will be real, inverted, enlarged, and located in front of the centre of curvature of the mirror. The IBAR display associated with the learning activity appears on the user's screen as shown in Figure 2.

By selecting this input marker, the IBAR display appears on the user's screen as shown in Figure 3. A convex mirror is the opposite of a concave mirror. Like a concave mirror, before describing the formation of an image, it is necessary to know the special rays possessed by a convex mirror. The special rays are as follows, the incident ray parallel to the principal axis will be reflected as if it came from the focal point, the incident ray as if going to the focus point will be reflected parallel to the principal axis, The incident ray towards the centre of curvature of the mirror, will be reflected as if originate from the same centre of curvature.With the help of the three special rays for convex mirrors above, it can be described the formation of images by convex mirrors. To form an image of an object located in front of a convex mirror, we simply use 2 special rays.

Figure 3. IBAR Display for Reflection of Light on a Convex Mirror



Formation of an image on a convex mirror image with a focal length of 10 cm, the image distance is -7.29 (behind the mirror). With a shadow height of 0.65, the magnification of the image is 0.27. in the display of light reflection on a convex mirror there is a menu option to change the image height and image distance. The user will be able to change the IBAR by scanning concave and convex lesions as shown in Figure 4 and Figure 5.

Figure 4. IBAR Display for Reflection of Light on a Concave Lens

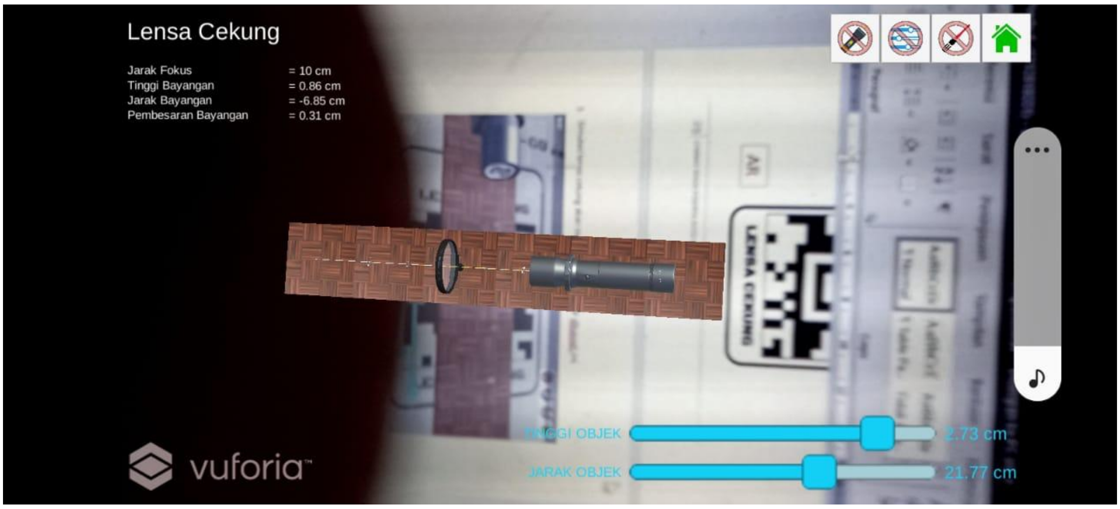


Figure 4. Information obtained that the focal distance is 10 cm, and the image distance is -6.85 cm. The working process of Reflection of Light on a Concave Lens The object distance is greater than the centre of curvature of the mirror (P2). The object distance is greater than P2, so by using a special ray of a concave lens, an image is obtained that is virtual, erect, reduced, and the location of the image is in front of the lens. This is evidenced by the height of the object 2.73 cm and the resulting image height of -6.85 cm, the height of the image is greater than the height of the object, the sign - means virtual. This shows that IBAR can show 3D objects that are like reality during real practicums. Figure 5 represents the IBAR display for Reflection of Light on a Convex Lens, the whole system was developed as a mobile application with a virtual practicum component 3D model on a convex lens.

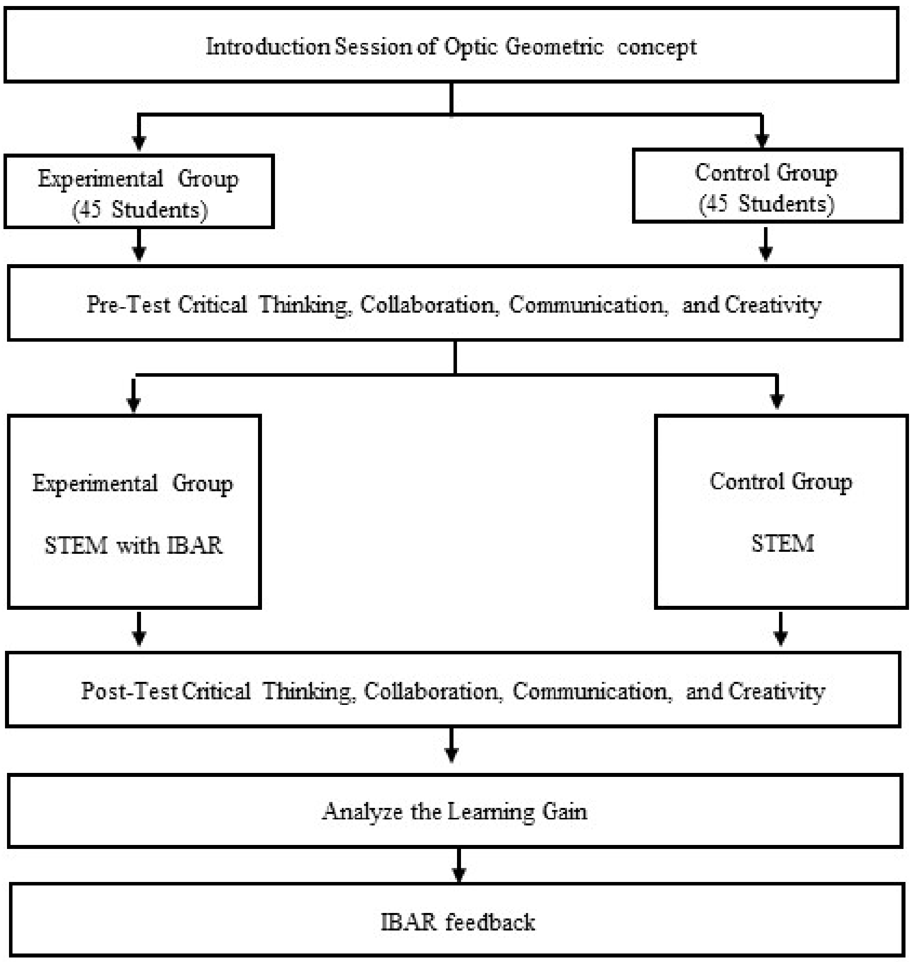
Figure 5. IBAR Display for Reflection of Light on a Convex Lens

The object distance is greater than the centre of curvature of the lens (P2), a flashlight as a light source provides an incident ray, if the object distance is greater than 21.77 cm from the centre of curvature of the lens (P2), using a special ray of a convex lens, a real, inverted image is obtained is reduced, and the position of the image is between the first focal point and the image distance is 18.5 cm.

In the experimental group this learning activity is based on voluntary participation, so that students participate according to their respective interests. In this study, it was also informed that the pre-test and post-test scores would not affect the lecture evaluation scores. After the introductory session, students were randomly divided into two groups: the IBAR-assisted STEM teaching group and the no-battle STEM teaching group or the conventional group. Students were randomly divided into two groups who did not know about the experimental study, thus ensuring a complete random distribution. After the distribution of students, individual pre-tests were conducted to evaluate 21st century skills consisting of Critical Thinking, Collaboration, Communication, and Creativity tests on optical phenomena and to examine the similarity of learning abilities of the two groups on the same subject. In the pre-test, students were given a test consisting of 16 questions in the form of a description related to optical geometry material where they had to answer each question by writing answers. The time limit given to students to complete the pre-test is 80 minutes with a maximum score for the pre-test of 64. The IBAR-assisted STEM teaching group consists of 45 students who are trained with IBAR assistance and the conventional STEM teaching group without IBAR also consists of 45 students who are taught with conventional lecture-based approach. During the learning process, the IBAR-assisted STEM teaching group provides lessons using IBAR-assisted STEM to understand the principles of Reflection of Light on a Concave Mirror, Reflection of Light on a Convex Mirror and Refraction of Light on a Concave Lens, and Refraction of Light on a Convex Lens. The students were instructed in understanding the workings of concave mirrors and convex mirrors with the help of IBAR. Previous studies have shown that students have difficulty understanding optical geometry concepts about how rays travel, especially in virtual images (Kaltakci, et al., 2016); (Kaltakci, et al., 2018).

STEM learning activities assisted by IBAR or not carried out lasted for 120 minutes for each group. After the learning activities, students from both groups were asked to do the post-test. The post-test consists of 16 questions in the form of a description, each sola has a weighted score of 4 for each number and with a maximum score of 20. The time limit for completing the post-test is 80 minutes for both groups. After the post-test, interviews were conducted in the IBAR-assisted STEM teaching group and the IBAR-assisted STEM teaching group to provide their feedback and suggestions about IBAR. Figure 6 describes the research design for completing the IBAR-assisted STEM process.

Figure 6. Experiment design STEM assisted by IBAR



2.3. Measuring

The measurement instrument used in this study consisted of a Critical Thinking, Collaboration, Communication, and Creativity test about optical phenomena. In this IBAR study, the 21st-Century Skills test consists of Critical Thinking, Collaboration, Communication, and Creativity on AR which is used as a data collection tool.

2.3.1. Critical Thinking Test

The Critical Thinking test is based on tests developed by researchers themselves that have been validated by experts. The test consists of 5 description questions with a reliability coefficient of 0.78 good category. These test questions are based on Critical Thinking indicators and core competencies of the concept of atomic core structure according to the curriculum. Critical Thinking Indicators used in the research are formulating problems, analysing arguments, asking, and answering questions, evaluating, and defining (Wechsler, et la., 2018).

2.3.2. Collaboration Test

This collaboration test is based on a test developed by the researcher himself that has been validated by an expert. The test consists of 5 description questions with a reliability coefficient of 0.70 good category. This test question is based on the Collaboration Indicator used in this study, namely the skills to work together, synergize with each other, adapt in various roles and responsibilities, and respect differences of opinion when learning using IBAR.

2.3.3. Communication Test

This communication test is based on tests developed by the researchers themselves which have been validated by experts. This test consists of 5 description questions with a reliability coefficient of 0.68 good category. This test question is based on Indicator Communication, namely listening skills, writing skills, oral skills that occur during learning using IBAR.

2.3.4. Creativity Test

This Creativity test is based on a test developed by the researcher himself that has been validated by an expert. The test consisted of 5 essay questions with a reliability coefficient of 0.72, either category. This test question is based on the Creativity indicator and core competencies from the concept of the atomic core structure according to the curriculum. Creativity indicators used in the research are asking questions, guessing the causes, guessing the consequences of an event, improving the output (Wechsler, et la., 2018).

3. Results and Discussion

3.1. IBAR for Improving 21-CS

The application of IBAR in learning that facilitates the development of 21st-Century Skills (21-CS) is shown by the Critical Thinking, Collaboration, Communication, and Creativity data that has been collected and from experimental research analysed with SPSS software to determine research results. Before applying statistical tests to the data that has been collected, the first thing to do is test the normality of the data. Table 2 presents descriptive statistics for pre-test, post-test, Critical Thinking, Collaboration, Communication, and Creativity which shows that the data are normally distributed, so that the independent sample t-test can be used to determine the difference between the two groups.

Table 2. Descriptive Statistics of Pre-test and Post-test of Critical Thinking, Collaboration, Communication, Creativity

Test	21st-Century Skills (21-CS)	N	M	SD	SE
Pre-Test	Critical Thinking	90	12.48	4.12	0.62
	Collaboration		11.42	3.84	0.62
	Communication		13.48	5.06	0.62
	Creativity		12.36	4.42	0.62
Post-Test	Critical Thinking		14.68	5.26	0.62
	Collaboration		13.88	4.18	0.62
	Communication		15.81	6.88	0.62
	Creativity		14.45	5.34	0.62

*SD: Standard Deviation, SE: Standard Error.

Based on Table 2, information is obtained that the Pre-test and Post-test data of Critical Thinking, Collaboration, Communication, Creativity are normally distributed. This means that the ability between students used is almost the same or a data forms a normal distribution if the amount of data above and below the mean is the same. This means that the sample used has a high level of normality.

t-test was conducted to determine the 21st century skills of students about the ability of Critical Thinking, Collaboration, Communication, Creativity about the basics of Physics on optical concepts. Table 3 presents the t-test analysis of the pre-test and post-test which shows that there is no significant difference between the mean scores of the two groups $p > .05$. After implementing STEM with IBAR, Levene's test was carried out to determine the similarity of variance of post-test scores for the two groups. The p value of Levene's test is greater than 0.05 and with an F value of 0.682, which indicates that there are insufficient data to conclude the difference in variance for the two groups. Thus, the same variance was assumed between groups, then a t-test was performed to determine the difference in knowledge between the two groups after the intervention. Table 4 presents the t-test analysis of the post-test scores, the mean value of the post-test scores for the STEM teaching group with IBAR was 16.80 and that for the conventional STEM teaching group or without IBAR was 13.25 with $p < 0.05$, which indicates that there is a significant difference between the knowledge acquisition of the two groups. Cohen's d value for the post-test was 1.67, indicating a large effect size. Based on the data analysed by the post-test, it was found that the IBAR intervention in STEM learning has a major impact on 21st century skills consisting of Critical Thinking, Collaboration, Communication, Creativity.

Table 3. t- test Analysis of Pre-test and Post-test of Critical Thinking, Collaboration, Communication, Creativity

Dependent variable	**Group**	**N**	**Mean**	**SD**	**t**	**df**	**p**	**Cohen's d**	**<g>**	**95% Confidence interval of the difference**	
										Lower	**Upper**
Pre-Test	Teaching STEM with IBAR Experimental Group	45	12.60	3.08	- 0.38	88	.929	-0.04	2.5	-1.73	-1.73
	Teaching STEM Control Group	45	12.40	3.43					2.4		
Post-Test	Teaching STEM with IBAR Experimental Group	45	16.80	2.87	6.78	88	.000	1.67	6.7	2.57	4,98
	Teaching STEM Control Group	45	13. 25	2.46					5.9		

Table 3 provides information on the average score of the Pre-test of Critical Thinking, Collaboration, Communication, Creativity in the conventional control group applying STEM-based learning 12,40. While the pre-test score in the experimental group using STEM assisted IBAR the average score is 12,60. Cohen's d score for the ability of Critical Thinking, Collaboration, Communication, Creativity is 1,67 which indicates a large effect size of IBAR-assisted STEM in learning in the control group that only applies STEM.The average gain score <g> Pre-Test Teaching STEM with IBAR Experimental Group 2.5 and Post-Test Teaching STEM with IBAR Experimental Group 6.7 experienced an increase in the average score gain <g> with the medium category of Critical Thinking skills, Collaboration, Communication, Creativity. And in the conventional group the average gain score <g> Pre-Test Teaching STEM control Group 2.5 and Post-Test Teaching STEM control Group 5.9 experienced an increase in the average score gain <g> with low category Critical Thinking skills, Collaboration, Communication, Creativity.

3.2. Developmentand Implementation of IBAR-assisted STEM Activities

In this study, IBAR-assisted STEM learning activities were carried out within the scope of the optical geometry concept. The application was carried out for 4 times face-to-face online for 2 weeks in the concept of reflection on the mirror, and refraction of light on the lens. The learning objectives and IBAR-assisted STEM activities are given in Table 4. Each activity begins with a scenario containing a real-life engineering problem.

Students complete a 3-stage inquiry cycle and 2-stage engineering design process to solve engineering problems given in concurrent scenarios.

Table 4. Learning objectives and IBAR-assisted STEM Activities for each lesson

STEMActivities	LearningObjectives	Science	Technology	Engineering	Mathematics
1. Uncover the phenomenon of light "Light Illusionist".	- Linking the causes of light pollution to environmental changes. - Analyse light reflection events and angle limits.	Laws of refraction and refraction in light, reflection events	Laws of refraction and refraction in light, reflection events	Create and apply designs that depict the phenomenon of light pollution due to environmental changes by illusionists or simulations demonstrated by IBAR during demonstrations.	Mathematical calculations related to Snell's law
2. IBAR Film Show Lenses	- Explain the properties of lenses and types of lenses. - Describe the nature of the image formed by the lens. - Create a picture of the formation of the image in the lens.	The incident ray in the image of a thin lens, the incident ray at	The incident light is in the image of a thin-eyed lens; special light is comingthick lens in picture in IBAR	Storyboard Product development app design to be prepared to watch pictures and movies	Determine the focus and point by measuring and mathematical calculations according to the type of lens to be used
3. Mirror and Lens Combination	- Find a combination of using mirrors that reflect light and using lenses - Create designs to solve light pollution problems - Create a design proposal that has the characteristics of a light project	Reflection of concave mirrors and convex mirrors, collects or distributes light in the lens	Reflection in the mirror, collecting or distributing light in the lens using IBAR	The design and application of the product that will be used to draw a solution to overcome light pollution	Determine the point of formation of the shadow usingcombination of plane mirror and lens with mathematical measurement

The stages of IBAR-assisted STEM learning and the engineering design process for dealing with light pollution are given in Table 4. In this process, students are involved in processes such as identifying problems, gathering information needed for solutions, identifying hypotheses, and designing virtual experiments to test. Paying attention to the experimental results, students make designs to solve problems and develop their designs with creative ideas being trained. IBAR in this study acts as a tool to help apply concepts during the science and engineering stages of STEM activities. Students conduct research to develop solutions of possible light pollution problems to engineering problems. In this context, they have designed and conducted a virtual experiment using IBAR to test solution hypotheses. Students develop a model with IBAR and try to find the most appropriate solution. IBAR provides opportunities for students to experiment independently using their respective smartphones on the concept of optical geometry. The IBAR teaching group uses STEM-based learning with the help of IBAR while the conventional teaching group uses STEM-based learning without using IBAR. The results showed that the STEM-based learning environment assisted by IBAR had a significant positive impact on students' Critical Thinking, Collaboration, Communication, and Creativity compared to the STEM teaching group without using IBAR. The IBAR experience helps students visualize abstract concepts of Physics and when phenomena of a microscopic nature can be understood.

3.3. Discussion

The urgency behind this research is to optimize Interactive Book Augmented Reality (IBAR) for Lesson on Student STEM to improve 21st-Century Skills (21-CS) on geometric optical concepts. In this study, IBAR was developed which aims to provide an active learning experience to students about the concept of optical geometry which consists of Light Reflection on a Concave Mirror, Reflection of Light on a Convex Mirror and Refraction of Light on a Concave Lens, and Light Refraction on a Convex Lens. The experimental results show that the IBAR teaching group uses STEM-based learning with the help of IBAR while the conventional teaching group uses STEM-based learning without using IBAR. The results showed that the STEM-based learning environment assisted by IBAR had a significant positive impact on students' Critical Thinking, Collaboration, Communication, and Creativity compared to the STEM teaching group without using IBAR. The IBAR experience helps students visualize abstract concepts of Physics and if microscopic phenomena can be understood by students, then macroscopic phenomena will also be easy to understand. In terms of 21-CS, the average post-test score of the IBAR-assisted STEM teaching group compared to the post-test score of the conventional STEM teaching group, shows that the implementation of IBAR has a significant positive effect on Critical Thinking, Collaboration, Communication, and Creativity on the optical geometry concept. The use of IBAR has the advantage of an attractive visual appearance because it can display 3D objects and their animations as if they were in a real environment and juxtaposed with information about 3D objects. In addition, the merging of objects in the virtual world (virtual) into the real world in the form of two or three dimensions that can be touched and seen.

In fact, AR is very supportive in the field of education, this can be seen from the following research results AR can increase student learning interest (Cai S. et al., 2017), (Abdusselam & Karal, 2020), (Fidan & Tuncel, 2019), (Sahin & Yilmaz, 2019). AR can also increase students' learning motivation (Hanafi, et al., 2017) and (Saadon, et al., 2020). AR can facilitate learning (Akcayir, et al., 2016). AR can concretize abstract concepts (Radu & Schneider, 2019). AR can develop spatial abilities (Guntur, et al., 2019). AR can develop collaboration and interaction between students (Radu & Schneider, 2019). AR can increase mastery of concepts (Fidan & Tuncel, 2019) and (Yoon, et al., 2017). AR can also improve students' science attitudes (Sahin & Yilmaz, 2019). AR can improve laboratory skills (Akcayir, et la., 2016). AR can improve learning outcomes (Cai, et al., 2017) and (Abdusselam & Karal, 2020). AR can support creativity (Ivanova & Ivanov, 2011). AR can improve problem solving (Guntur, et al., 2019). Furthermore, AR can improve critical thinking skills (Anggraini, et al., 2019).

Based on interview results IBAR shows very good results and is suitable for use as a learning medium, both in class and independently. Student response to the use of IBAR media in learning is very good. Students are enthusiastic in participating in learning and arouse student curiosity. AR can be used to bridge the gap between practical and practical theoretical learning together with real and virtual components blended to create a unique learning experience. AR in education is proven to be effective for several purposes, such as better learning performance, learning motivation, student engagement and positive attitude.

> *"Student responses to the IBAR are included in the very good category because the average score obtained is above 3.4. This shows that the IBAR learning media AR the concept of optical geometry can be used in the learning process."*

In addition, several parties revealed a negative aspect of IBAR, namely that every student does not necessarily have a smartphone because it is in areas, especially areas far from urban areas. In addition, internet signal for downloading and IBAR software is also a problem. Many researchers have developed AR learning platforms that can be used in education as a means of student engagement in learning activities.

4. Conclusion

The college environment plays an important role in shaping sustaining healthy eating habits among youngsters. Overall, the results of this study support the fact that IBAR can improve the 21st century skills of Critical Thinking, Collaboration, Communication, and Creativity of students. The IBAR teaching group uses STEM-based learning with the help of IBAR while the conventional teaching group uses STEM-based learning without using IBAR. The results showed that the STEM-based learning environment assisted by IBAR had a significant positive impact on students' Critical Thinking, Collaboration, Communication, and Creativity compared to the STEM teaching group without using IBAR. The IBAR experience helps students visualize abstract concepts of Physics and if microscopic phenomena can be understood by students, then macroscopic phenomena will also be easy to understand. Students are motivated and enthusiastic and motivated to learn through the IBAR platform. During the 2020 coronavirus disease pandemic, AR and VR technologies can help teachers and academics to support effective learning environments and provide engaging and immersive learning experiences. It takes a lot of time and money to develop an IBAR, but academic institutions support funding to assist researchers in developing this IBAR because it will be a useful resource for students and teachers during online learning.

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