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Development of Augmented Reality Learning Media Based on Inquiry Based Learning Using Assemblr Edu on Light and Properties Material

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A B S T R A C T

This study aims to develop Augmented Reality (AR)-based learning media using an Inquiry-Based Learning (IBL) approach through the Assemblr Edu platform, focusing on light and its properties for fifth-grade elementary students. The background of this research lies in the low conceptual understanding of students due to the limited use of interactive and contextual learning media. The research used a Research and Development (R&D) method adapted from the 4D model, involving needs analysis, media design, expert validation, product trials, and dissemination. Data were collected through interviews, questionnaires, and documentation, and analyzed qualitatively and quantitatively. Validation results from material experts (94.28%) and media experts (82.66%) indicated that the media was "highly feasible." Small-scale trials involving 11 students showed a high interest rate (93.93%), demonstrating that AR media significantly enhanced students' engagement and understanding of abstract concepts such as reflection, refraction, and light transmission. The findings conclude that AR-based learning media with an IBL approach is effective in improving students' comprehension and motivation, offering an innovative solution to enhance the quality of science learning in the digital era.

1. Introduction

Nowadays, humans are highly dependent on technology. This makes technology a basic necessity for everyone. From children to adults, experts to laymen, everyone uses technology in various aspects of their lives. Technology today has developed very rapidly. The rapid development of information technology in the current era of globalisation cannot be ignored in terms of its impact on the world of education (Ana & Muzzaki, 2023). Global demands require the world of education to adapt to technological developments to improve the quality of education, particularly in terms of adjusting the use of information and communication technology for the

world of education, especially in the learning process (Made et al., 2024). Therefore, to address the challenges of the globalisation era, students require certain skills to master, one of which is cognitive thinking ability. Higher-order thinking skills are one of the cognitive abilities outlined in the 2013 Curriculum (Faiqoh et al., 2019).

According to Sadiman & Arief (2019), the use of technology is essential for improving students' understanding through learning media. Students tend to be more interested and find it easier to comprehend when the learning process incorporates animation. The use of media helps teachers deliver material more effectively, creating a livelier and less monotonous learning environment. One form of media that has proven effective is animation, as it can present complex concepts visually and dynamically, making them easier for students to grasp(Daly et al., 2016). Students' interest in technology-based media such as animation also encourages active engagement in the learning process, which ultimately enhances learning outcomes (Puspita & Sitepu, n.d.).

Studies in several elementary schools indicate that 27.49% of students hold misconceptions and 32.07% have misunderstandings about light and its properties. These percentages indicate that most students have not yet correctly grasped the basic concepts. One of the main factors contributing to this issue is the limited use of interactive and engaging learning media. Learning that relies solely on verbal explanations, without the support of visual media or teaching aids, makes it difficult for students to visualize abstract scientific processes such as reflection, refraction, and the direction of light propagation. Consequently, these concepts become challenging for students to understand in depth. Therefore, learning media that can improve students' understanding through more active and enjoyable learning experiences are needed, so that the material can be absorbed more easily and accurately.

Interviews show that elementary schools in the Jatilawang Korwilcam area face problems such as a lack of learning media and limited technology. Although some Chromebooks are available, the number is not enough. Most schools have LCDs or projectors, but they are not used effectively. There is also a shortage of skilled teachers in using technology. Currently, most schools only have one or two LCDs, and only about 20% have TVs for learning. Technology-based media are important to improve teaching and learning in line with 21st-century needs. Therefore, schools in this area need new educational innovations.

Based on teacher interviews, the lack of learning media can make it difficult for students to understand the material, especially abstract topics such as light and its properties. Without adequate media, students tend to become bored and lose interest, which decreases their motivation to learn. As a result, they often resort to memorizing rather than truly understanding the concepts. The heavy reliance on the lecture method also makes students passive, as they only listen to the teacher's explanations with minimal interaction, limiting their opportunities to explore the material independently. Therefore, the use of engaging and interactive learning media is essential to help students better understand the material and avoid

conceptual misunderstandings. One solution in the digital era is the use of Augmented Reality (AR) with an Inquiry-Based Learning (IBL) approach.

Augmented Reality (AR) is a technology that combines the real and virtual worlds, showing two- or three-dimensional objects in a real environment at the same time (Mustaqim et al., n.d.). It is designed to create visualizations and develop 3D content that can be viewed through mobile devices (Mardian et al., 2023). Its easy-to-use interface lets students explore 3D images that make learning materials clearer and more interesting (Elektro et al., 2021). When combined with the Inquiry-Based Learning (IBL) approach, AR can make learning, especially in Natural Sciences, more effective. IBL encourages students to ask questions, investigate, and find answers through exploration and experiments. Using AR, students can see 3D objects, run virtual experiments, and discuss ideas with classmates. This helps improve their critical thinking and problem-solving skills while making learning more engaging and meaningful (Mukaromah, 2024).

Research by Setiawaty et al. (2024) integrated mobile-based AR technology with an inquiry learning approach in science education. Using a quasi-experimental method, the study examined the effect of AR media on students' science process skills and conceptual mastery. The results showed that using mobile AR applications within an inquiry framework significantly improved students' scientific skills and conceptual understanding (Prajayana et al., 2025). Another study developed "SIAR" (Augmented Reality Water Cycle) learning media for fifth-grade elementary school students. This media utilised AR technology to visualise the water cycle process interactively and engagingly. Expert validation and student trials indicated that the media were valid, practical, and effective in enhancing conceptual understanding of the water cycle. However, although the research demonstrated the success of AR in science learning, the content remained abstract, and the approach did not integrate IBL. Incorporating IBL is important to encourage students to actively explore and discover concepts through the scientific process (Rahmawati et al., 2024).

Based on preliminary studies in several elementary schools, students' understanding of light and its properties remains low. Many are unable to correctly explain concepts such as refraction, reflection, and absorption of light. This is largely due to the use of conventional, non-interactive learning media, making it difficult to grasp abstract concepts. Furthermore, students often show low enthusiasm during lessons. The use of engaging and contextual media is therefore essential to increase participation and understanding.

2. Methodology

This study employs the Research and Development (R&D) model using the 4-D model (Define, Design, Develop, and Disseminate). The Define stage includes needs analysis, student characteristics, and learning objectives. The Design stage involves designing an interactive 3D learning media using Assemblr Edu, equipped with visuals and quizzes. The Develop stage includes validation by subject matter

experts and media experts, limited trials with teachers and fifth-grade students, and product revisions. Finally, the Disseminate stage involves distributing the product to partner schools. Data were collected through interviews, questionnaires, and documentation. Instruments used included interview guides, validation questionnaires, and response questionnaires for teachers and students. The data were analyzed using both qualitative descriptive and quantitative methods to assess the feasibility of the product and the responses of teachers and students.

3. Results and Discussion

This development process adopts the 4-D model introduced by Thiagarajan, which includes four main steps: definition, design, development, and dissemination. Each step in this model is carried out in a gradual and structured manner to produce relevant, high-quality learning media that can meet students' needs to understand the material more effectively.

Define

The definition stage was carried out with the aim of comprehensively understanding the various needs related to media development, including basic concepts, evaluation forms, and learning specifications to be applied in Augmented Reality media. This process was carried out through a series of analyses, such as needs analysis, learner characteristics analysis, material analysis, and learning task analysis, so that it could become a strong foundation for designing media that is appropriate and effective for use in the classroom.

Front-End Analysis

This stage aims to identify the problems in the field before developing a product. A needs analysis was conducted through interviews and preliminary studies at a public school. Based on interviews with Korwilcam Jatilawang, it appears that schools in the Korwilcam Jatilawang area still face obstacles in providing learning media and technological facilities. Although most schools already have LCD/projectors and some Chromebooks, their use is still not optimal. Teachers' limited ability to use technology is also a problem in four elementary schools. A summary of the results of the teacher needs survey is shown in the following table 1 below:

Table 1. Results of Teacher Needs Questionnaire

No	Statement	Percentage	Description
1	I believe students still have difficulty understanding the topic of light and its properties	85%	The majority of respondents realize that the topic of light and its properties is quite difficult for students to grasp, thus requiring a more effective teaching approach and learning media.
2	I have used technology-based media such as Augmented Reality (AR) in teaching science (IPAS).	30%	Most teachers have not yet used AR media, indicating a low level

			of technology utilization in classrooms
3	I still frequently use lecture methods when teaching light and its properties.	70%	Many teachers still rely on traditional lecture methods, which may contribute to students' difficulties in understanding the material
4	In my opinion, students can understand the topic of light and its properties even without additional learning media.	65%	Some teachers believe additional media are not always necessary, suggesting a misconception about the importance of learning media.
5	I find it difficult to provide engaging and interactive media for teaching light and its properties.	85%	Teachers admit facing challenges in providing media that can capture students' attention and improve understanding.
6	I believe oral explanations and textbooks alone are not enough to help students truly understand the topic of light and its properties.	100%	All respondents agree that conventional methods are insufficient, and additional media are needed to enhance student understanding
7	I believe the lack of engaging and interactive media makes students easily bored in learning science (IPAS).	100%	All teachers realize that the absence of interesting media has an impact on students' low interest in learning.
8	I am aware of the Assemblr Edu platform for creating AR-based media.	35%	All teachers acknowledge that the absence of engaging media affects student interest and motivation.
9	In my opinion, science learning without interactive media makes students get bored easily.	100%	Only a few teachers are familiar with Assemblr Edu, indicating a need for further training or socialization
10	I support the development of a new AR-based media to help students better understand the topic of light and its properties.	100%	All teachers agree that interactive media are crucial to keeping students engaged in science learning

Based on the results of the teacher questionnaire, it can be concluded that the majority of teachers are aware of students' difficulties in understanding the material on light and its properties, mainly due to the learning method which is still predominantly lecture-based, and the minimal use of interactive learning media. Most teachers have never used Augmented Reality (AR) media, and only a few are familiar with platforms such as Assemblr Edu. All respondents stated that verbal explanations and textbooks are not enough, and the lack of interesting media makes students easily bored. Therefore, all teachers support the development of new AR-based learning media to help students more easily understand the material on light and its properties more concretely and interestingly.

Learner Analysis

At this stage, it was found that most students felt bored when learning using only textbooks. On the other hand, the use of interesting and interactive media made them more enthusiastic and easier to understand the material. Researchers also explored the characteristics and understanding of students through interviews and

questionnaires, the results of which showed the need for varied and interactive learning media. The results of the student needs questionnaire are shown in Table 2 below:

Table 2. Results of The Student Needs Survey

Statement	Answer
I have difficulty understanding the topic of light and its properties.	40 students reported having difficulty understanding light and its properties, while 14 students did not experience any difficulties.
I feel bored when learning about light and its properties because the teacher does not use engaging learning media.	24 students felt bored during the lesson due to the lack of engaging media, while 20 students did not feel bored.
I find it difficult to visualize the concept of light and its properties.	35 students stated they had difficulty imagining the concept of light and its properties, while 17 students did not have this difficulty.
I feel bored during lessons on light because the teacher only uses the lecture method.	26 students reported feeling bored during the lessons, while 26 students did not feel bored.
I have difficulty understanding light because interactive learning media are rarely used in class.	25 students reported difficulty understanding the material due to the absence of interactive media, while 24 students felt they could understand the material even without it.
I find it hard to understand the topic of light because the teacher does not use visual aids or teaching tools, making the explanation unclear and hard to imagine.	34 students stated that without visual aids or teaching tools, the explanation was hard to understand, while 22 students felt they could still understand it.
I feel the need for technology-based learning media.	41 students expressed the need for technology-based learning media, while 11 students did not feel the need.
I am interested in trying new technology-based learning media.	46 students stated they were interested in trying technology-based learning media, while 6 students showed no interest.
I am interested in trying Augmented Reality media based on Assemblr Edu in classroom learning.	45 students expressed interest in trying Augmented Reality media using Assemblr Edu, while 7 students were not interested or were still unsure.
I understand lessons on light more easily when using technology-based learning media.	42 students felt they understood light concepts better when using technology-based learning media, while 10 students felt there was no difference.

Interview and questionnaire results indicated that 40 students had difficulty understanding the light topic, 24 students felt bored, and 35 students had difficulty visualizing the concept. Forty-one students needed technology-based media, 46 students were interested in trying new media, and 45 students were interested in using Assemblr Edu-based Augmented Reality. This demonstrates the importance of developing technology-based learning media.

Concept Analysis

At this stage, researchers analyzed the main concepts to be incorporated into Augmented Reality (AR)-based learning media, namely material on light and the properties of light. This analysis aimed to ensure that all important aspects of these concepts could be presented accurately, coherently, and in a manner that was easy for students to understand. These key concepts are then broken down into learning

stages based on the Inquiry-Based Learning (IBL) approach, which includes several steps: an orientation stage to spark students' curiosity about the phenomenon of light; formulating problems related to the properties of light; developing hypotheses based on initial understanding; collecting data through observation or exploration using AR media; testing hypotheses through designed learning activities; and finally, guiding students to formulate conclusions based on the data and findings they obtained during the learning process. Thus, AR media not only conveys information but also facilitates students' active engagement in the scientific thinking process.

Task Analysis

At this stage, the learning process involved not only explaining the concept of light and its properties, but also integrating the use of Augmented Reality technology through the Assemblr Edu platform within the framework of an Inquiry-Based Learning approach. Through this method, students were guided to actively engage in a series of structured learning activities that included observing three-dimensional visualizations, exploring interactive simulations, asking in-depth questions, formulating hypotheses, and testing their understanding through problem-solving tasks. The combination of AR technology and IBL created a dynamic and immersive learning environment where students could visualize abstract concepts such as reflection, refraction, and light transmission more concretely. This process not only encouraged curiosity and critical thinking but also fostered collaboration among peers, enabling students to construct their own knowledge through exploration and discovery.

Specifying Instructional Objectives

This stage is designed to provide students with the opportunity to directly engage with Augmented Reality (AR) media as a means of gaining a deeper and more comprehensive understanding of the various properties of light. Through the immersive visualizations and interactive simulations available on the AR platform, students are able to explore abstract phenomena such as reflection, refraction, and light transmission in a concrete and visually rich manner. The learning process encourages students to not only passively observe but also to actively analyze the phenomena presented, identify patterns, compare results, and develop hypotheses based on their observations.

Design

In the design stage, researchers develop learning media based on the needs analysis from the definition stage. The process includes creating an initial blueprint for the Augmented Reality (AR) media, selecting accurate and curriculum-aligned content, and determining effective presentation methods that balance text, visuals, and interactivity. Visual elements such as color schemes, typography, and layout are carefully planned to make the media appealing and easy to navigate. Interactive features are designed to encourage active student participation, enabling them to explore and experiment with AR content. The goal is to produce media that supports

learning objectives while providing an engaging and immersive learning experience.

Media Selection

After the learning objectives were clearly formulated in accordance with the basic competencies to be achieved, the researchers continued the development process by creating interactive 3D models that illustrate various light phenomena, such as refraction, reflection, and absorption of light. Each 3D model was equipped with explanations in the form of narrative text, visual descriptions that support conceptual understanding, and interactive quiz questions designed to evaluate the level of student understanding directly after interacting with the media. To support optimal media presentation, the researchers chose the Assemblr Edu platform because this platform has a user-friendly interface, is easy to operate by both teachers and students, and is able to display Augmented Reality (AR) objects with clear, realistic display quality and can be accessed via smartphone devices, making it very suitable for use in learning in elementary schools.

Format Selection

In this stage, researchers developed and designed an instrument format, consisting of a text instrument, used to assess the media's suitability and collect feedback. This instrument consisted of validation sheets for subject matter experts and media experts with a rating scale of 1 to 5. The assessment covered several aspects, including visual appearance, presentation style, and language use. Additionally, a response questionnaire was developed for teachers and students. The teacher questionnaire used a 5-point Likert scale, while the student questionnaire was presented with "Yes" or "No" responses to better reflect student characteristics.

Intial Design

In this stage, researchers developed the initial design for the Augmented Reality (AR) media developed in the previous stage into a preliminary product ready for testing. This initial design was a prototype AR-based learning media for the topic "Light and Its Properties" in the fifth grade science subject of elementary school. This media was developed using the Assemblr Edu application, which can display three-dimensional (3D) objects so students can directly observe simulations of the properties of light, such as light passing through transparent objects, light reflection, and light refraction. The following preliminary design can be seen in Figure 1 and 2 below:

Develop

The development phase is the realization of the product design prepared in the previous phase. The designed learning media is then implemented in the form of an initial product (prototype) that is ready for testing. This media has the advantage of being able to present light phenomena realistically through AR-based 3d visualization, thereby helping student understand science concepts more easily,

interestingly, and enjoyably. This development phase aims to assess the feasibility of the learning media and produce an Assemblr-based Augmented Reality product through two main stages.

Figure 1. Preliminary Design

Figure 2. Light Passing Through a Transparent Object

Validation Test

The product validation stage is a crucial step in evaluating and assessing the quality of previously developed learning media. This process involves assessments by experts with competencies in their respective fields, such as subject matter experts and media experts, to ensure that the developed media meets the eligibility standards in terms of content, visual appearance, language, and integration with the learning approach used. This validation aims to identify weaknesses or deficiencies in the media so they can be corrected before being tested on students. This ensures that the resulting media is not only visually appealing but also effective, relevant, and aligned with the desired learning objectives.

Material Expert Validation

Expert validation focuses on the suitability of the content, quality, and presentation. The aspects assessed include the adequacy of the material, the accuracy of the science concepts, and the suitability of the presentation for primary school students. The results of the expert validation are shown in Table 3 below:

Table 3. Validation by Material Experts

Indicator	Number of Items	Skor	Max Score	Average	Percentage
Quality	1	4	5	4	80%
Content	3	15	15	5	100%
Presentation	3	14	15	4.67	93,93 %
Total	**7**	**33**	**35**	**4,71**	**94,28 %**

The validation results from material experts showed a percentage of 94.28%, thus meeting the validity criteria. Therefore, Augmented Reality (AR) media is suitable for use in the learning process.

Media Expert Validation

Media expert validation aims to assess the technical aspects of media display, such as visual design, ease of navigation, 3D images quality, clarity of voice narration, and media interactivity. Based on the validation results, the media was declared suitable for use because of its attractive design, easy navigation for students, and effective use of 3D visuals to aid concept understanding. The results of the media expert validation can be seen in Table 4:

Table 4. Media Expert Validation

Indicator	Number of Items	Scor	Max Score	Average	Percentage
Visual Appearance	4	18	20	4,50	90%
Presentation	4	16	20	4,00	80%
Language	3	12	15	4,00	80%
Inquiry Based-Learning (IBL)	4	16	20	4,00	80%
Total	**15**	**62**	**75**	**4,13**	**82,66%**

The validation results from the material experts showed a percentage of 82.66%, thus meeting the validity criteria. Therefore, Augmented Reality (AR) media is suitable for use in the learning process.

Media Trial Phase

This product was tested on a small scale involving 11 participants in grade V of SD Negeri 5 Kedungwringin. The aim was to determine the extent to which the media was attractive and suitable for use in learning. During the implementation, students were asked to scan a barcode and access a link to Assemblr Edu, which contained materials on light and its properties using an Inquiry-Based Learning approach.

After the learning activity was completed, students were asked to fill out a questionnaire to provide feedback on the learning media. The results of the analysis of student responses can be seen below in Table 5:

Table 5. Results of Student Response Analysis

Indicator	Yes	No	Total Scor Ideal	Percentage
Statement 1	11	0	11	100,00 %
Statement 2	11	0	11	100,00 %
Statement 3	9	2	11	81,82 %
Statement 4	11	0	11	100,00 %
Statement 5	11	0	11	100,00 %
Statement 6	9	2	11	81,82 %
Total	**62**	**4**	**66**	**93,93 %**

The criteria for student responses can be seen below in Table 6:

Table 6. Student Response Criteria

Percentage	Criteria
81-100%	Very Interesting
61-80 %	Interesting
41-60 %	Soewhat Interesting
21-40 %	Not Interesting
0-20 %	Very Not Interesting

Source: (Riduwan, 2015)

The results of the Augmented Reality learning media trial used in the learning process showed an excellent response from students. Of the 11 students who completed the questionnaire, the majority answered "yes" to all questions. The total score obtained was 62 out of a maximum of 66, representing a percentage of 93.93%. This indicates that the developed learning media is very interesting to use in learning, as it helps students more easily understand the material on light and its properties.

Disseminate

The dissemination stage is the final and crucial step in the development process, serving the primary purpose of introducing and promoting the learning media that has been carefully designed and refined so that it can be effectively utilized by a wider range of users, particularly teachers and students. At this stage, the finalized media—having undergone thorough revisions and improvements based on feedback from subject matter experts, media specialists, and trial participants—is systematically prepared for broader use. Dissemination activities may include presenting the media in workshops, training sessions, or seminars to equip educators with the necessary skills to integrate it into their teaching practices. Additionally, the media is distributed to partner schools, educational communities, and other relevant stakeholders who can benefit from its implementation in classroom learning. Efforts are also made to provide accompanying guides, tutorials, or instructional materials to ensure smooth adoption and effective usage. Through this process, the developed media is not only introduced as a product but

also as a practical, innovative tool capable of enhancing the quality of teaching and learning experiences in various educational settings.

Validation Testing

The researchers conducted socialization of Inquiry-Based Learning Augmented Reality learning media in three schools, namely SDN Taman Sari, SDN 2 Pliken, and SDN 1 Pliken, as well as prospective teachers. There were 20 teachers and 18 prospective teachers. The results of the teachers' responses can be seen in Table 7:

Table 7. Results of Teacher and Prospective Teacher Responses

No	Respondents	Number of Respondents	Percentage (%)	Category
1	Teachers	20 Teachers	89,41 %	Very Good
2	Prospective Teachers	Prospective Teachers 18	96,21 %	Very Good
	Total		**92,81**	**Very Good**

Once the results are known, the next step is to perform an analysis with the scores converted into percentages (%). The criteria for analyzing teacher responses can be seen in Table 8:

Table 8. Teacher Response Questionnaire Criteria

Percentage (%)	Teacher Response Criteria
81-100	Very Good
61-80	Good
41-60	Fairly Good
0-40	Poor

Source: (Riduwan, 2015)

Packaging

The developed Augmented Reality media is packaged in the form of a barcode that can be scanned using a smartphone, making it easy for users to access learning content practically and quickly. To support the use of this media, learning instructions and a guidebook are also provided, containing complete information on the steps that must be taken by students and teachers in using this Augmented Reality media. The guidebook includes how to access the barcode, technical instructions for using the application, and a guide to learning activities that support interactive and fun understanding of the concept.

Diffusion and Adoption

Through direct socialization activities with teachers and prospective teachers. In addition, the researchers also shared media links with the Head of the Jatilawang Sub-district Coordination Unit, who then distributed them to the principal group in order to reach more parties. Several teachers showed interest in trying and introducing the media, although there were still obstacles such as time constraints and the need for further training.

4. Conclusion

This research successfully developed an Augmented Reality (AR)-based learning medium with an Inquiry-Based Learning (IBL) approach using the Assemblr Edu platform, specifically designed for the topic of light and its properties in fifth-grade elementary schools. This medium was developed as a solution to the limitations of existing interactive media, which often made it difficult for students to understand abstract concepts such as reflection, refraction, and absorption of light. Through a development process involving needs analysis, interactive content design, expert validation, and limited trials, this medium was able to provide more engaging, contextual, and understandable learning. The expert validation results showed that the medium met the eligibility criteria in terms of content, presentation, language, and suitability for the learning approach used. Trials with students demonstrated very positive responses, both in terms of interest, active engagement, and ease of understanding. Teachers also assessed that this medium could help them deliver material more effectively and with more variety. Thus, this IBL-based Augmented Reality learning medium was deemed feasible and effective for use in science learning. This innovation is expected to encourage a more active, creative, and enjoyable learning process, while also improving the quality of learning in the digital era.

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