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Design and Effectiveness Augmented Reality of Greenhouse Effect Integration Model Physics Independent Learning

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Abstract

Augmented Reality (AR) can positively impact learning and provide authentic experiences in the form of simulations by increasing enthusiasm for learning and activities in the classroom. This research aims to develop the design and effectiveness of the Augmented Reality Greenhouse Effect (ARGE) Integration Model Physics Independent Learning (MPIL) and explore the results of the product and their application in physics learning. The ARGE application will be implemented in universities located in the central part of Indonesia ARGE presents a simulation of learning tools to train lecturers and students with the implementation of AR technology, which aims to transfer real learning experiences to understand the concept of the Greenhouse Effect. The research method chosen in the ADDIE method was carried out on 127 students and integrated with MPIL. The number of these students participated in research, where they were divided into three student groups: (i) Semester 3 (N= 42), (ii) Semester 5 (N= 42), and (iii) Semester 7 (N= 43). After 12 weeks of lectures, most students stated a significant positive confirmation of ARGE implantation. These results revealed that the application of ARGE MPIL based on testing the effects of the product by students had excellent practicality in teaching in relevance with a percentage of 92.38%. Then the self-confidence aspect obtained a percentage of 94.29%, and the satisfaction aspect received a percentage of 97.14%. The ARGE design is integrated with MPIL developed to properly simulate the Greenhouse Effect concept. ARGE is effectively categorized as an excellent medium for learning the Greenhouse Effect concept.

Keywords: Augmented Reality, Greenhouse Effect, Integration, Model Physics Independent Learning.

Introduction

Education is fundamental in creating awareness among young people (Yang, 2022). Unsurprisingly, many countries have started incorporating climate change into school curricula. In Indonesia, climate change material is taught in physics lessons, namely in the global warming material section. This material contains the basic physics concepts, namely heat radiation, reflection, and absorption of heat radiation by greenhouse gases (Anderson et al., 2016). This will be difficult for students to understand because it cannot be observed directly or is microscopic. Therefore, until now, students need clarification about this topic (Daniel, Stanisstreet, and Boyes, 2004; Shepardson et al., 2009, 2012).

Higher education should prepare the Independent Learning (IL) Campus to face social change, the world of work, and technological advances, according to the needs of the times (Ahmad, 2019; Jackson, 2019); Link and match with the world of industry and the world of work (Wadee & Padayachee, 2017). Universities are required to design and implement innovative learning based on the demands of independent learning (Landry, 2019) and problem-solving skills (Balta & Asikainen, 2019). IL is a form of flexible

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learning, so an innovative learning culture is created by the needs of students (Abidah et al., 2020). Another challenge is in the form of global issues with the birth of 21st Century Skills (21-CS), which is termed 4C (Communication, Collaboration, Critical Thinking, Creativity) (Sulaiman & Ismail, 2020) and the transformation of the education sector towards the industrial revolution 4.0 (Catal & Tekinerdogan, 2019). In addition, the preliminary study's results revealed that the 4C skills in physics concepts were low in the low category.

Augmented Reality (AR) is an immersive and interactive technology when computer-generated digital information such as video, graphics, animation, text, or sound is interactively integrated into real-world visions (Craig, 2013; Wardana et al., 2023). AR bridges the gap between reality and virtuality (Cai et al., 2014). AR interacts with the natural world rather than fully with virtual environments (Fidan & Tuncel, 2018). AR is divided into two categories: (i) image-based and (ii) location-based (Cheng & Tsai, 2013). AR can be used indoors or outdoors on mobile devices and computers. It is, therefore, possible to organize ubiquitous experiences in formal and informal settings (Wu et al., 2013). In recent years, the use of AR in science education has become increasingly widespread, as well as in various educational fields such as mathematics (Estapa & Nadolny, 2015) and geometry (Lin et al., 2015). AR has been implemented in the field of science education, especially in physics (Akçayır et al., 2016), biology (Küçük et al., 2016), chemistry (Cai et al., 2014), and astronomy (Yen et al., 2013). AR is suitable for the nature of science thanks to its realistic structure, the concretization of the subject, facilitation of experimentation, and focus on investigation or examination (Yoon et al., 2017). AR can increase student achievement in the learning process and stimulate their positive emotions in science education (Akçayır et al., 2016; Hwang et al., 2016). More specifically, the results obtained from empirical studies have shown that students who use AR technology have a higher achievement (Wu et al., 2017), attitudes (Akçayır et al., 2016), and motivation (Chiang et al., 2014) when compared to traditional methods in science education. Furthermore, AR facilitates understanding of science courses by reducing students' cognitive load (Küçük et al., 2016) and growing their attention to it (Chiang et al., 2014).

The AR technology developed interactive applications that support AR software teaching magnetic fields or magnetic induction. Their study results show that it can improve student learning outcomes. In physics courses, AR applications for convex imaging experiments are practical tools for increasing students' attitudes, motivation, and attention (Cai et al., 2017).

Climate change is a severe global phenomenon and attracts world attention because it can be a factor in natural disasters such as drought, extreme weather, and floods (Melillo et al., 2014). Climate change occurs due to changes in the composition of the global atmosphere due to increased concentrations of greenhouse gases (Mikhaylov et al., 2020). This is thought to be caused by human activities; fast action can partly overcome climate change (Baste & Watson, 2022). One way to convey the knowledge needed to deal with global climate problems locally is through education (Yuan et al., 2022). Further explanation regarding material that has many misconceptions includes (1) the greenhouse effect; (2) the concept of the ozone layer; (3) acid rain; (4) the occurrence of La-Nina and El Nino. This problem is allegedly closely related to physics learning which is carried out in schools that are still conventional, and the unclear presentation of textbooks (Fauzi & Chano, 2022); (Wibowo, 2023). Lecture method learning is only verbal information and does not facilitate students to construct or fully understand the concept, namely the phenomenon of the greenhouse effect. For example, the greenhouse effect contains the basic concepts of physics, namely heat radiation, reflection, and absorption of heat radiation by greenhouse gas molecules; this, of course, cannot be directly observed by the sense of sight. If this phenomenon can be visualized, the material will be easier to understand. Therefore, learning media is needed to visualize this phenomenon.

The Independent Learning (IL) for the Physics model is an innovative science learning model that can encourage each individual to solve problems using a scientific approach (investigation, collaboration, discussion, and presentation) to bridge the gap between graduates' competency expectations and conditions in the field according to the demands of the IL curriculum (Ministry of Education and Culture, 2020; Griffin & Care, 2015; Pandiangan et al., 2017). The IL model is an innovative science learning model that can encourage everyone to solve problems and teach the stages of problem-solving to think critically and have independence, whereas, in physics learning, individual transitions in the thinking process must be ensured at each stage of problem-solving (Ersoy & Güner, 2015). The development of the IL model uses a scientific approach with methods of inquiry, assignment, collaboration, discussion, and presentation so that it can bridge the gap between graduates' competency expectations and conditions in the field according to the demands of the 21st century and the curriculum for implementing the Indonesian National Qualifications Framework (KKNI) (Griffin & Care, 2015). The IL model syntax applied in this study is a learning model consisting of six phases, namely: (1) Initiation and Persistence, (2) Responsibility, (3) Self

and Group Investigation, (4) Analysis, (5) Presenting and Discussion, and (6) Strengthening and Evaluation. The primary purpose of this developed model is to improve students' problem-solving skills and independent learning skills. This designed learning model is expected to give students high independence in problem-solving activities (Stadler et al., 2020).

However, the AR that has been developed has yet to integrate with the Physics Independent Learning model. Therefore, the researcher tries to open further development by referring to the findings and results of the study above; it is deemed essential to develop the Augmented Reality Greenhouse Effect (ARGE), which is integrated with the Physics Independent Learning (MPIL) Model and its effectiveness when used by the student. In addition, the developed ARGE Model with MPIL must be able to provide solutions to the limitations of teaching materials and can reduce learning implementation time, which can show Greenhouse Effect simulations to microscopic visualizations.

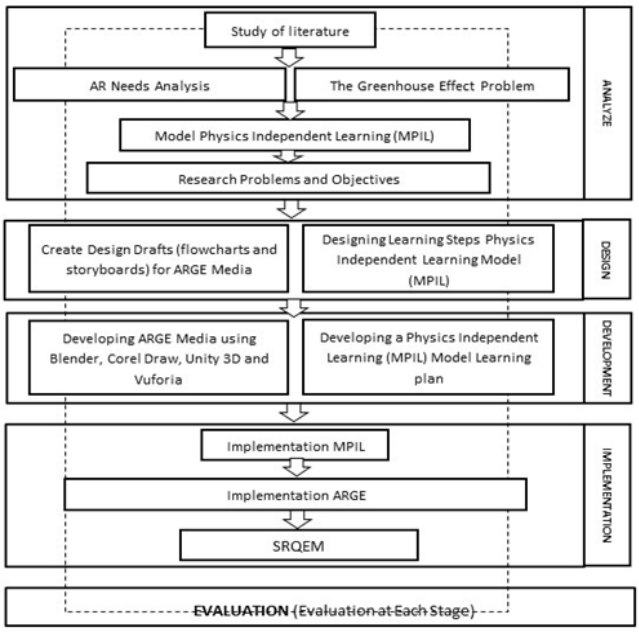


Fig. 1: ARGE Integration MPIL Research Design

Method

Research and development used in ARGE development research is a process or steps to develop new products or improve existing products. Research and development are the development of solutions to complex educational problems using scientific inquiry. Researchers and developers seek to solve significant real-world problems while, at the same time, they seek to discover new knowledge that can inform others when faced with similar problems (McKenney & Reeves, 2014). The ADDIE research consists of Analysis, Design, Development, Implementation, and Evaluation (Richey et al., 2019).

Research Design

The research design chosen in this study was ADDIE, with the product being developed in the form of Augmented Reality Greenhouse Effect (ARGE) Integration media (Model Physics Independent Learning (MPIL). Data collection tool used is a Student Response Questionnaire Effectiveness Media (SRQEM) and the procedure research is described in full in Figure 1.

Figure 1 description of the developed ARGE media was integrated with student worksheets. Generally, the research procedure can be illustrated as a Concrete and detailed step. The solutions resulting from educational design research can be educational products (e.g., virtual world-based multi-user learning games, processes (e.g., strategies for student learning in online courses), programs (e.g., workshop series intended to help teachers develop more effective strategies learning), or policies. They were deliberately chosen because it aims to develop and produce ARGE products that will be used to solve a problem in the learning process with the MPIL method. In addition, this research is used to test research products in the form of hardware and software. The research results went through several stages of manufacture, from needs analysis to evaluation.

Sample for Study

The number of samples selected and used in research using the ADDIE research method is 127 students and integrated with MPIL. The number of students participating in the research where they are divided into three student groups: (i) Semester 3 (N = 42), (ii) Semester 5 (N= 42), and (iii) Semester 7 (N= 43). After 12 weeks of lectures, most students expressed significant positive confirmation of ARGE implantation.

Figure 1 Description Design of Implements ARGE Integrated MPIL in the first week, the pretest was carried out with SRQME. Furthermore, learning was carried out using Learning Integrated Using ARGE with MPIL at the 2nd to

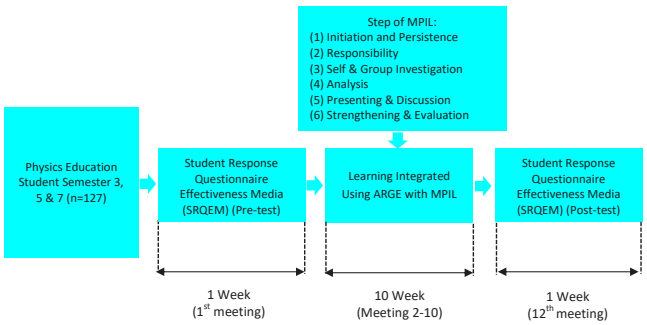


Fig. 2: Design of Implements ARGE Integrated MPIL

10th meeting. Meanwhile, the twelfth week was carried out with a post-test to see students' responses to this media. Furthermore, the pretest and post-test scores were processed with normalized gain to see an increase in response before and after using ARGE media.

Data Collection Tools

The data collection tool used is a Student Response Questionnaire Effectiveness Media (SRQEM), which measures the effectiveness of ARGE media by students using a student response questionnaire to see student responses to ARGE media that have been developed and applied in learning activities. The following is a questionnaire grid to determine student responses to the ARGE media shown in Table 1.

Table 1. Indicator Student Response Questionnaire Effectiveness Media (SRQEM) media ARGE

Indicator	*Observed indicators*	*Number Questions*
Relevance	Interest Focus and Attention Increase motivation	3
Confidence	Easy to use Helps in understanding building concepts Happy and enthusiastic	3
Satisfaction	The attractiveness of media design Ease of use	2

Data Collection

Data collection was used after SRQEM when testing ARGE media in the field for students. The next step is to collect and analyze data. Instruments are tools or facilities used by researchers in collecting data to make their work easier and the results better, i.e., more accurate, complete, and systematic so that it is easier to process than a sample of 127 students. The instruments used in research to collect data are in Table 2.

Table 2 description of SREQM is used to obtain information about student responses to the ARGE in learning the Greenhouse Effect concept. This questionnaire contains a list of questions related to ARGE in the Greenhouse Effect learning. This response questionnaire instrument contains columns that strongly agree, agree, disagree, and strongly disagree. Students are asked to give a check mark (√) on the statements in the questionnaire.

Data Analysis

The data collected in this study are classified into quantitative data. The data were analyzed after the results were obtained through a questionnaire on the effectiveness with reliability of student responses (Hashim et al., 2020). The next step was to analyze the data. This study focuses on developing ARGE to analyze data using quantitative analysis techniques using value scale calculations, as shown in Table 3.

Table 3: Student Response Questionnaire Effectiveness Media (SRQEM) Score Scale

Score Scale	*Score*
Strongly agree	5
Agree	4
Doubtful	3
Disagree	2
Strongly Disagree	1

Furthermore, the results of the SRQEM research given to students are calculated in the following way:

% Respondents' Responses

$$= \frac{\sum \text{Respondents who answered}}{\sum \text{All Respondents}} \times 100\%$$

The percentage of scores obtained is then measured using score interpretation. To find out the Student Response Questionnaire Effectiveness Media category, can be interpreted in Table 4. SRQEM Score Percentage Scale and its Interpretation.

Table 4: Criteria Effectiveness for Student Response Questionnaire Media (SRQEM) ARGE

SRQEM Percentage	*Interpretation*
0% < SRQEM < 20%	Very Not Good
21% < SRQEM < 40%	Not good
41%< SRQEM < 60%	Enough
61%< SRQEM < 80%	Good
81%-< SRQEM < 100%	Excellent

Table 2: Data Collection Techniques

Data Type	*Technique*	*Data source*	*Instrument*
Student Response Questionnaire Effectiveness Media (SRQEM)	Checklist on the questionnaire sheet	Students	Questionnaire Effectiveness Instrument Student response to ARGE

Findings

Result of ARGE Media

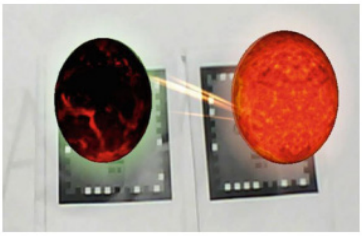
The results of Augmented Reality of Greenhouse Effect (ARGE) Integration Model Physics Independent Learning (MPIL) media development begins with AR, which other researchers have developed. Prior to development, an Analysis of the Availability of Augmented Reality Media on the Greenhouse Effect Concept was carried out. The development of AR media on climate change material has been carried out a lot. The following is an analysis of the availability of AR media on climate change material that has been developed by previous researchers and which has been published, as shown in Table 5.

Based on Table 5, information is obtained that some of the Augmented Reality media on the Greenhouse Effect concept still need improvement. Therefore, it is necessary to design advanced AR media development. In this study, the media to be developed is ARGE, which contains 3D animation in the greenhouse effect process. Furthermore, the design component of learning media design is a marker based ARGE application on an Android device.

a. ARGE specifications

The developed ARGE can display a 3D simulation of the greenhouse effect process. ARGE must be embedded in a smartphone that has an Android system. The size of the

Table 5. Analysis of the Availability of Augmented Reality Media on the Greenhouse Effect Concept

	Sulisworo et al., (2021)	AR learning media developed based on cards as markers and can display 3D animation about global warming. This media still needs to contain animation of the El Nino and La Nina phenomena.
	Parvathy et al., (2016)	The developed AR learning media can display 3D animations about illustrations of the earth heating up due to solar radiation and the leading cause of global warming, namely carbon dioxide produced from human activities.
	Kholiq (2020)	The learning media developed is an AR-based digital book that can visualize simple animations about the state of the earth under normal conditions and conditions during global warming. This media does not yet contain animations of the depletion of the ozone layer, acid rain, El Nino, and La Nina phenomena.
	Asembler edu https://play.google.com/store/apps/details?id=com.assemblr.education	The developed AR learning media is equipped with text, audio, and images but not with visualization of the physical processes of the greenhouse effect and other global warming material. acid, El-Nina and La-Nina.

AR Researchers	*Source*	*Explanations*
	Asembler edu https://play.google.com/store/apps/details?id=com.assemblr.education	The developed AR learning media contains a visualization of the physical phenomena of the greenhouse effect and other global warming material but is still very simple, besides that it is not equipped with audio, text, and instructions for use and does not yet contain material on the ozone layer, acid rain, El-Nina, and La-Nina.
	Our World - Experience Climate Change with Augmented Reality - YouTube	The developed AR learning media is equipped with text, audio, and images and with visualizations of the physical processes of the greenhouse effect and other global warming material. However, this media is not equipped with instructions for using the media and does not contain material on the ozone layer, El Nina, and La Nina.

ARGE application is 168 Mb, and the required storage space is 262 Mb. ARGE is an offline application, but you must be connected to the internet to download student worksheets.

b. ARC User Interface

User Interface (UI) is a visual display of a product that connects the system with the user. The UI developed includes an initial display, main menu display, manual user display, ARGE display, learning start display, developer profile view, and bibliography view.

c. ARGE Design

The ARGE media design that has been validated and revised based on suggestions and notes from experts contains the initial appearance, main page, instructions for use, about ARGE, getting started, downloading student worksheets, and bibliography. When the user opens the ARGE application, the initial display in Figure 3 to 10.

Fig. 3: Initial Display of ARGE Media

On the initial appearance of ARGE there is a title, a welcome sentence, the ARGE logo, the agency logo, and the "Start" button. The "Start" button directs users to enter the main page view. When clicking the "Start" button, the user will be directed to enter the main page view.

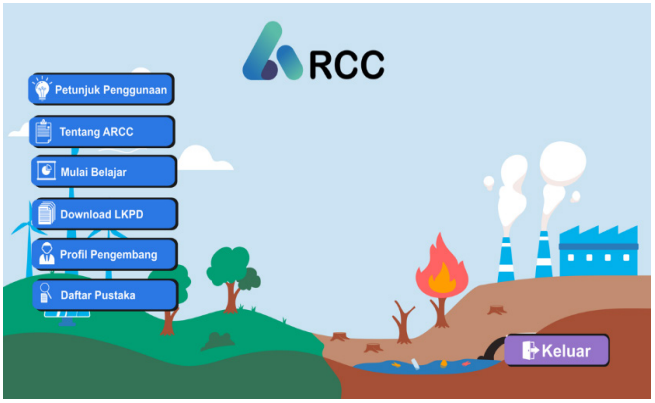


Fig. 4: Display Main Page

On the main page display, there are buttons "User Guide, About ARCC, Start Learning, Download student worksheets, Developer Profile, Bibliography, and Exit." The "Exit" button functions to exit the ARGE media. Then the "Instructions for Use" button functions to display information about instructions for using ARGE media. The user manual display contains graphic info about guidelines for using ARGE media, starting from the stages of downloading and installing applications to using ARGE media; besides that, users can also view video tutorials starting from the stages of downloading, installing, and using ARGE media via a link or by scanning. Barcodes that have been provided. The overall display of the user manual is shown in the following figure.

Fig. 5: Display Instructions for Use ARGE

The About ARGE button functions to display general information about ARGE media, including information about the features contained in this application, which can display 3D reality about the greenhouse effect, ozone layer depletion, acid rain, El-Nino, and La-Nina. The information about this application is integrated with student worksheets, and information about smartphone specifications that can use ARGE media or applications is a minimum of Android 4.1 (Jellybean) up to Android 12. Overall, the appearance of the page about ARGE is shown in the following figure.

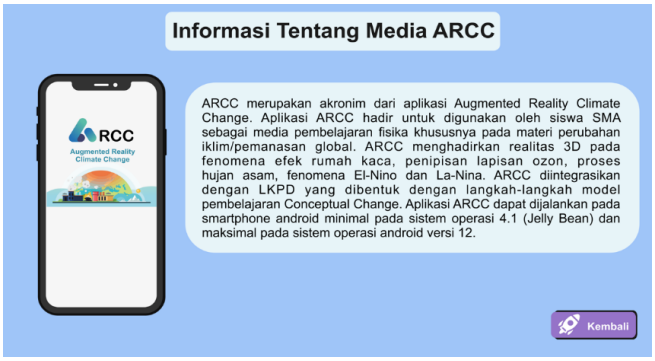


Fig. 6: View of ARGE

The "Download student worksheet" button links to the link to download the student worksheet file on Google Drive. When the user selects the "Download Student Worksheet" button, they will be directed to their respective Google Drive account, which can download and save the Student Worksheet file in PDF format on their Google Drive account or cellphone storage memory. The overall display of the download student worksheet is shown in the following figure 7.

The "References" button displays information about the references used in ARGE media. The references used come from books and videos originating from the YouTube platform with agency accounts about education so that they can be accounted for. The overall view of the bibliography is shown in the figure. 7

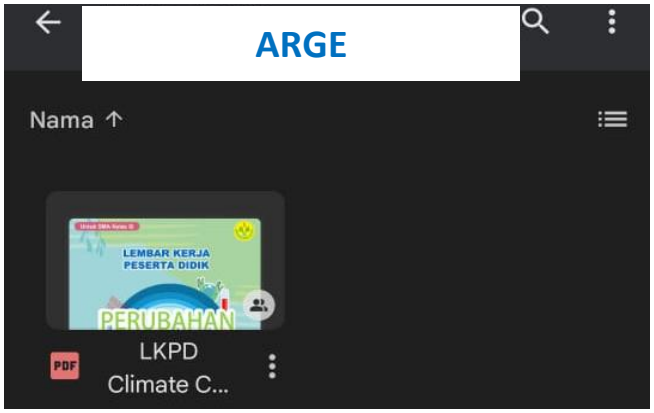


Fig. 7: Display Download Student Worksheet

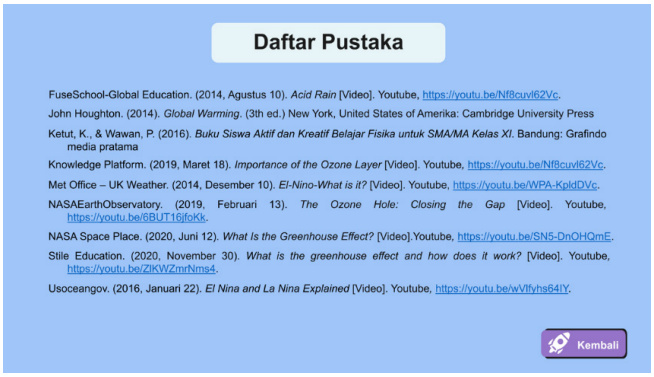
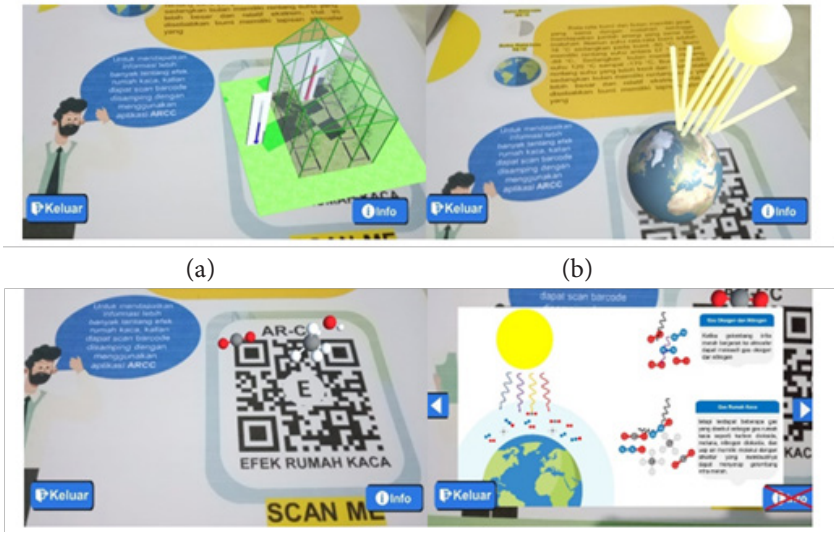


Fig. 8: References Display

"Start Learning" button to display the material to be studied, namely the process of the greenhouse effect, ozone layer depletion, acid rain, El Nino, and La Nina. The start learning display has several buttons according to the material the user will learn. The overall appearance of starting to learn is shown in the following figure 9.

Fig. 9: Display Start Learning

When the user clicks the greenhouse effect button, the user will be directed to a 3D simulation view of the greenhouse effect process. The initial view will display the



(a) (b)

(c) (d)

Fig. 10: Display of 3D Simulation and Explanation of Greenhouse Effect Material

camera view; the user needs to point the smartphone camera at the greenhouse effect marker in the student worksheet, then a 3D simulation view of the greenhouse effect process will appear, as shown in the following figure.

The forms of simulation that can be performed on this screen consist of three forms. Figure 10 displays a 3D simulation of the working principle of a greenhouse consisting of a greenhouse and a thermometer inside and outside the greenhouse. When solar radiation enters the greenhouse, some will be reflected, and some will be absorbed and trapped inside the greenhouse; this causes the temperature inside the greenhouse to be higher than outside the greenhouse. This can be observed by the increase in temperature on the thermometer inside the greenhouse, which is higher than the thermometer outside the greenhouse. This principle is like the workings of the earth's atmosphere, which makes the earth's temperature more stable, known as the greenhouse effect.

Effectiveness ARGE

The effectiveness of ARGE product results by students using the Student Response Questionnaire Effectiveness Media (SRQEM) instrument to 127 students at universities in the central district in Indonesia. Product by students is carried out by distributing the Student Response Questionnaire Effectiveness Media (SRQEM) after using the media. Product was given through a questionnaire with yes and no choices, with eight questions from 3 aspects. There are 127 students integrated with MPIL. After 12 weeks of lectures, most students expressed significant positive confirmation of ARGE implantation. These results reveal that the application of ARGE MPIL based on testing the results of the product by students has excellent practicality in teaching in relevance with a percentage of 92.38%. Then the self-confidence aspect obtained a percentage of 94.29%, and the satisfaction aspect obtained a percentage of 97.14%. ARGE media integrated with MPIL has positively impacted learning physics after the chest pandemic, as shown in Table 6.

Based on Table 6, it was found that 91.43% of students agreed that learning using ARGE was something new. As many as 94.29% of students thought that learning using ARGE could facilitate understanding of the material. As many as 91.43% of students felt that learning using ARGE could increase motivation in learning. As many as 94.29% of students thought ARGE could be easily used, helped them understand the material, and were happy and enthusiastic about learning. As many as 97.14% of students felt learning using ARGE was interesting and easy to understand and hoped AR-based media could also be applied to other materials. The percentage of product achievements by students on the relevance aspect is 92.38%. Then the aspect of self-confidence obtained a percentage of 94.29%. Furthermore, the satisfaction aspect obtained a percentage of 97.14%. It can be concluded that ARGE is categorized as an excellent medium for learning the Greenhouse Effect concept.

Discussion

The design and effectiveness of the Augmented Reality Greenhouse Effect (ARGE) Integration Model Physics Independent Learning (MPIL) and explore the results of product application in physics learning. The research results positively impact learning and provide real experience in the form of AR simulations by increasing enthusiasm for

Table 6: Results of Student Response Questionnaire Effectiveness Media (SRQEM) ARGE

No.	*Aspect*	*Percentage SRQEM*
Relevance		
1	Learning using ARGE-based learning media is a new lesson implemented in our school.	91,43%
2	The ARGE learning media facilitates me in understanding Greenhouse Effect	94,29%
3	The ARGE learning media used in physics learning further increases my motivation to study Greenhouse Effect	91,43%
Confidence		
4	I feel that the ARGE learning media used in learning is easy to use and easy to understand	94,29%
5	The ARGE learning media in physics learning can help me understand the greenhouse effect	94,29%
6	I feel happy and enthusiastic about using ARGE learning media.	94,29%
Satisfaction		
7	I feel that the ARGE learning media used in learning is exciting and easy to understand	97,14%
8	I enjoy using AR-based learning media and hope it can be used in other materials.	97,14%

learning and activities in class (Wong et al., 2021; Erdoğan & Bozkurt, 2022). ARGE presents a simulation of learning tools to train lecturers and students with the implementation of AR technology, which aims to transfer real learning experiences to understand the concept of the Greenhouse Effect (Volioti et al., 2022). After 12 weeks of lectures, most students stated significant positive confirmation of the implantation of ARGE. These results reveal that the application of ARGE MPIL based on Figure 10 (b) shows how the greenhouse effect works in the layers of the Earth's atmosphere; the animation shown is light. The sun that goes to the Earth then hits its atmosphere, some of it will be reflected, and the other part will be forwarded to the Earth's surface. This aims to explain that when electromagnetic radiation from the sun, which has different wavelengths, hits the atmosphere and the Earth's surface (Rohli et al., 2021), about 70 percent of the energy remains on Earth, absorbed by the soil, plants, oceans, and other objects. Then the remaining 30% percent will be reflected by clouds, ice, and other reflective surfaces. However, the absorbed heat is not always on Earth. The Earth's surface will reflect some heat into outer space as infrared waves. When infrared waves move into the atmosphere and hit several gases known as greenhouse gases, such as carbon dioxide, methane, nitrogen dioxide, and water vapor, they have molecules with a structure that allows them to absorb infrared waves (Soeder, 2021). This can be observed in the simulation. Figure 9(c).

Figure 10 (c) shows a 3D simulation of several greenhouse gas molecules: carbon dioxide, methane, and nitrogen dioxide. When infrared waves hit greenhouse gas molecules, they will be absorbed and reflected so that greenhouse gases can trap heat from infrared waves. This can be observed from the arrow lines moving towards the gas molecules, which are then absorbed and reflected; this is like a pinball game so that heat can be trapped on the Earth's surface. In Figure 9 (d), there is additional material to broaden students' understanding because it uses media (Wibowo et al., 2023; Wardana et al., 2023). This material explains how the greenhouse effect occurs, the impact caused when the concentration of greenhouse gases is in normal conditions, and when there is an increase in the concentration of greenhouse gases which can cause global warming, as well as solutions to overcome these problems. Through explanations from 3D simulations and additional material, this can remediate misconceptions that occur in students about the greenhouse effect, including (1) The depletion of the ozone layer causes global warming, (2) The greenhouse effect is not a natural phenomenon, (3) The greenhouse effect glass is a phenomenon that only has negative impacts on human life. Then the self-confidence aspect obtained a percentage of 94.29%, and the satisfaction aspect obtained a percentage of 97.14%. ARGE media developed integrated with MPIL has a positive impact on post-pandemic physics learning.

The greenhouse effect is a natural phenomenon that occurs due to the presence of gases that absorb and emit infrared radiation. These gases are called greenhouse gases (John, 2014). Greenhouse gases are gases in the atmosphere that absorb the thermal radiation emitted by the Earth's surface, having an enveloping effect on it. The most important greenhouse gas is water vapor, but its amount in the atmosphere does not change directly due to human activities (Woods et al., 2023). The greenhouse gases that are directly affected by human activities are carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), and chlorofluorocarbons (CFCs). Without the natural greenhouse effect, the average air temperature on Earth's surface would be

below the freezing point of water. This greenhouse effect has a positive impact on the Earth because it can keep the Earth's temperature more stable; during the day, heat radiation from the sun is partially absorbed and reflected, while at night, the heat is absorbed by the atmosphere and the Earth's surface is slowly released because of differences in temperature during the day and night day is not too extreme. This causes the Earth's temperature more stable and habitable compared to other planets. Thus, Earth's natural greenhouse effect made life as it is today possible. With ARGE media, students can absorb the material and facilitate thinking about the process of occurrence (Rosmiati, et al., 2023) and the consequences of the greenhouse effect to learn contextually from a medium.

Conclusion, Suggestion and Limitation

The ARGE-integrated MPIL learning media design has been successfully developed and received an outstanding category according to student. ARGE gets an excellent category so that ARGE can be used as a physics learning medium in the Greenhouse Effect for students. This learning media is equipped with a student worksheet developed as a learning aid and has the following characteristics (1) Realtime 3D simulation displays macroscopic and microscopic phenomena in the greenhouse effect material. (2) Equipped with navigation buttons and instructions for use (in the form of infographics and videos) so that it is easy to use (user-friendly). (3) Appearance is attractive and informative because it is equipped with additional material in the form of text, graphic info, and audio.

The results of this cheerful ARGE design also have several drawbacks because they only address the concept of the Greenhouse Effect. Results This work has several limitations that need to be improved for future work. The ARGE application is developed for Android, and the current version does not support other operating systems. ARGE is not qualified to be embedded in the iOS system (iPhone Operating System) because it is built specifically for the Android system. ARGE is accessible to a broader audience to achieve significant gains for exporting this application to other mobile operating systems. Another area for improvement is the language used; currently, we follow the independent Indonesian curriculum and do not support multilingual content. In addition to recommendations, AR media development can be carried out on other climate change materials, such as hydrometeorological disasters. Apart from that, development can also be carried out on other abstract physics material that contains microscopic phenomena. This study focuses on aspects of basic knowledge competence only. Therefore, teachers can add other activities to the student worksheet in the MPIL, such as project activities for making tools or conducting research related to the material to accommodate fundamental competency aspects of skills.

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