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Validation Results of Augmented Reality Media on Climate Change and Analysis of Students' Prior Knowledge on Global Warming Material in the "Kurikulum Merdeka"

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ABSTRACT

This study aims to analyze the development process of augmented reality media on climate change and global warming created by the researcher, evaluate the assessment results by experts on the augmented reality climate change media, and analyze students' prior knowledge of climate change and global warming material. The research was conducted using a descriptive quantitative method with data analysis supported by SPSS software. The augmented reality media on climate change was developed through the Assemblr Studio web platform, covering topics such as global warming, the greenhouse effect, ENSO, La Niña, El Niño, and the neutral phase. The findings indicated that the media development procedure was analyzed using guidelines, both for developing the media and for its use. Furthermore, the analysis of students' prior knowledge in understanding climate change and global warming material showed satisfactory results. The impact of AR media on climate change and global warming materials includes the ability to enhance global awareness, increase scientific knowledge and environmental care attitudes, as well as foster proactive actions to reduce greenhouse gas emissions that cause global warming and lead to climate change. Future research is needed to analyze students' literacy understanding after the implementation of the augmented reality climate change media.

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INTRODUCTION

Enhancing students' literacy on global warming is crucial, considering that climate change is one of the greatest challenges facing the world today. With strong literacy skills, students will gain a deeper understanding of the causes, impacts, and measures that can be taken to mitigate global warming(Hayati & Mufit, 2023; Kholiq, 2020; Salsabila et al., 2019). The use of Augmented Reality (AR) flipbook-based learning media offers an innovative solution to enhance this literacy, as AR can present information in an interactive and engaging way, making the complex concept of global warming easier to comprehend (Karpudewan, 2024; Rebello et al., 2024; Zapata-Paulini et al., 2023). A flipbook is an electronic medium that offers interactive simulations, combining text, images, videos, audio, and navigation to create an engaging learning experience (Susanti et al., 2020). In the meantime, Augmented Reality is a medium capable of transforming images into 3D forms (Wibowo et al., 2024). Through three-dimensional visualization and realistic simulations, students can directly observe how global warming affects the environment, thereby increasing their awareness and involvement in this issue (El Shemy et al., 2025; Lin et al., 2024; Prasetya et al., 2024).

This initiative aligns with the Sustainable Development Goals (SDGs), particularly Goal 13, which focuses on addressing climate change, and Goal 4, which aims to provide inclusive quality education (Ram et al., 2023; UNESCO, 2017). Through the use of Augmented Reality (AR), students not only gain knowledge but also a more meaningful learning experience, which resonates with the spirit of quality education(Barcena-Vazquez et al., 2023; Harun et al., 2020). Additionally, this approach supports the concept of "*Merdeka Belajar*" (Independent Learning) within the "*Kurikulum Merdeka Belajar*," encouraging more independent, creative, and innovative learning through technology. Therefore, integrating AR into global warming literacy education not only helps students understand this crucial issue but also equips them with the skills and knowledge needed to face future challenges.

The use of interactive media, such as Augmented Reality (AR), plays a crucial role in enhancing students' awareness of global warming (Prasetya et al., 2024; Zapata-Paulini et al., 2023). Through AR, students can observe three-dimensional visualizations of the impacts of global warming, such as the greenhouse effect process, the occurrence of global warming, melting polar ice caps, rising sea levels, and ecosystem damage in a direct and realistic manner(Negi, 2024; Wibowo et al., 2024). This more immersive learning experience makes it easier for students to understand abstract concepts, allowing them to grasp the urgency of the global warming issue(Fidan & Tuncel, 2019; Prasetya et al., 2024). Therefore, interactive media like AR not only makes learning more engaging but also encourages students to be more concerned and involved in environmental conservation efforts.

Before implementing the media in physics learning on global warming, it is essential to first evaluate the results of media validation. This step is crucial for providing assessments, feedback, and suggestions regarding the Augmented Reality (AR) learning media developed before it is applied to students (Karpudewan, 2024; Wulandari et al., 2021, 2024). This evaluation ensures that the AR content aligns with the learning objectives, is relevant, and is easily understood by students. Additionally, feedback from experts, teachers, and potential users can help identify any shortcomings or areas that need improvement, making the AR media more effective and engaging in conveying information about global warming. Through a thorough evaluation process, the AR media can be refined to provide an optimal learning experience and enhance students' awareness of the importance of environmental conservation.

Research Objectives:

1. To analyze the development process of augmented reality media on global warming and climate change material.
2. To analyze the validation results of the Augmented Reality media on global warming material.
3. To analyze students' initial understanding of physics material related to global warming and climate change.

RESEARCH METHOD

Research Process

This study is a type of descriptive quantitative research that analyzes expert evaluations. Before developing the media, the researcher conducted observations on the phenomena of global warming and climate change, starting from selecting the content, ideas, and objects to be created in the process of developing augmented reality media. Next, the researcher distributed instruments to students to assess their initial knowledge of global warming and climate change material. The overall research process is summarized in Figure 1.

Data or Sample Collection

In the aspect of media evaluation by expert validators who assess the results of augmented reality media, there are three experts involved. The evaluation conducted by these experts includes an expert in earth science, an expert in physics, and an expert in educational media.

Furthermore, the research team conducted a Focus Group Discussion (FGD) to align perceptions. For the sample collection in analyzing students' initial understanding, 30 students were randomly selected from six physics classes.

Data Analysis

The process of analyzing validation data used the percentage of agreement, with the "mode" being selected as the final result. Meanwhile, the analysis of students' initial understanding of the global warming and climate change material was conducted using descriptive quantitative analysis, followed by calculating the average results. The final results of students' initial abilities in the global warming and climate change material were adjusted according to the interval format in Table 1.

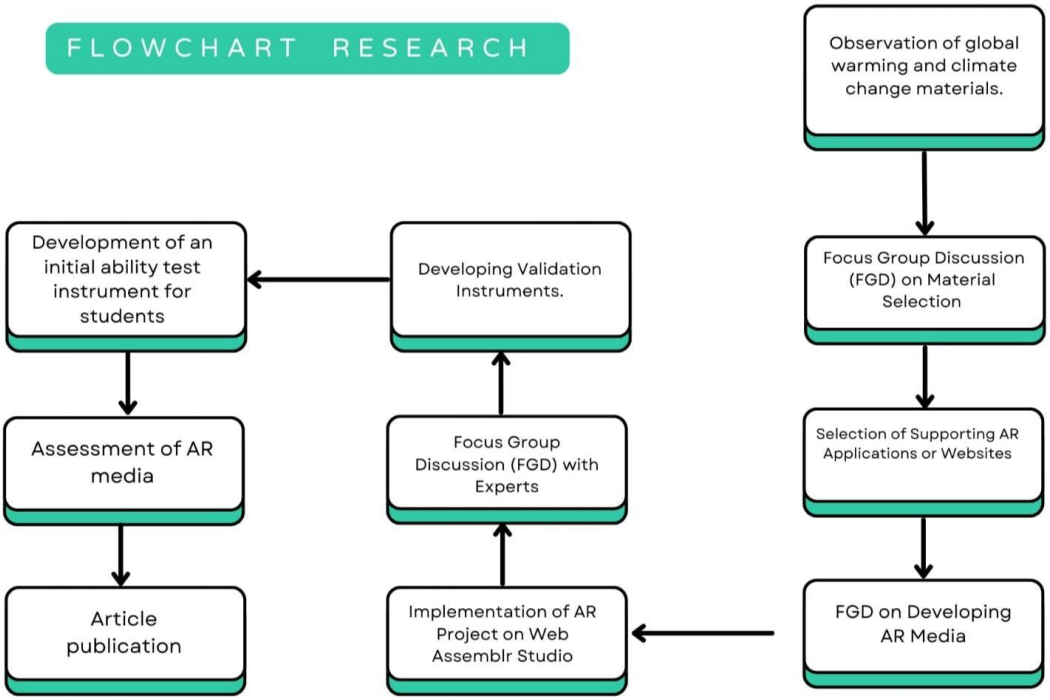


Figure 1. Flowchart research

The research begins with observing the phenomenon of climate change and global warming, including its impacts on both national and international scales. Observations are conducted by reviewing information from various types of literature, including research articles, print media, and social media. Once the topics to be discussed are identified, the next step is the development of media. Media is developed using websites and applications such as Canva and Assemblr. The global warming and climate change media is evaluated by validators (experts) and assessed accordingly. Subsequently, research instruments are designed. The test instruments are distributed, and the results are analyzed. Finally, the research findings are published in the form of an article.

Table 1. Assessment interval of students' final scores on climate change

Interval	Grade	Conversion Value	Title
91 – 100	A	4.00	Outstanding
81 ≤ X ≤ 90	A-	3.5	Excellent
71 ≤ X ≤ 80	B+	3	Good
61 ≤ X ≤ 70	B	2.5	Fairly good
51 ≤ X ≤ 60	C+	2	Satisfactory
41 ≤ X ≤ 50	C	1	Poor

Interval	Grade	Conversion Value	Title
0 – 40	D	0	Very poor

(Adapted : Wulandari et al., 2024)

RESULTS AND DISCUSSION

Development of Augmented Reality Media for Global Warming and Climate Change

The process of developing augmented reality media was carried out through several steps conducted by the researchers. Figure 2 shows the guidelines for developing augmented reality media for the topic of global warming and climate change.

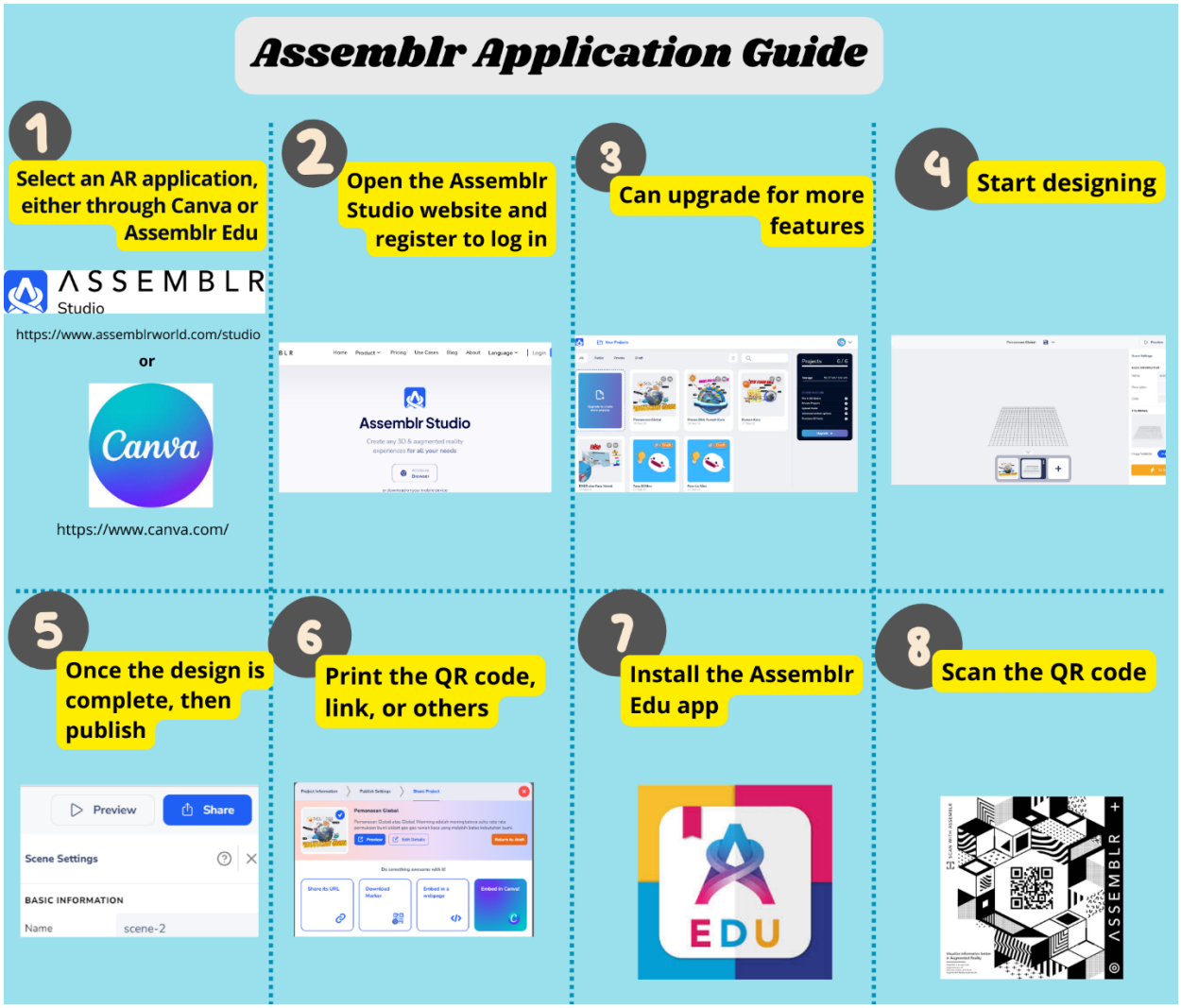


Figure 2. Guidelines for developing AR media through Assemblr studio

Figure 2 presents the guidelines for developing AR media using Assemblr Studio. The selection of Assemblr Studio as a tool for developing AR media is based on several aspects, such as easy accessibility, a user-friendly menu that facilitates a smooth media creation process, and straightforward access for students once the media is completed (El Shemy et al., 2025; Lin et al., 2024; Upadhyay et al., 2024; Zapata-Paulini et al., 2023;). However, there are minor challenges, such as edited and added menus or features that sometimes fail to appear after scanning. This issue is attributed to unstable internet connectivity. Furthermore, Figure 3 outlines the instructions for using the AR media on global warming.

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Figure 3 summarizes the instructions for using AR media on global warming and climate change. There are four media generated from QR barcodes that have been developed by the researchers. The content of these four QR media, when scanned with the Assemblr Edu application on Android, will display the visualizations of the material. The selection of these topics was derived from a Focus Group Discussion (FGD) involving the research team and several experts in the fields of earth science, physics, and educational media development. Next, the results of the augmented reality media on global warming and climate change are presented in Figures 4 and 5. When one of the above QR barcodes is scanned, it will display a visualization that includes 2D and 3D images or text containing information on global warming and climate change.

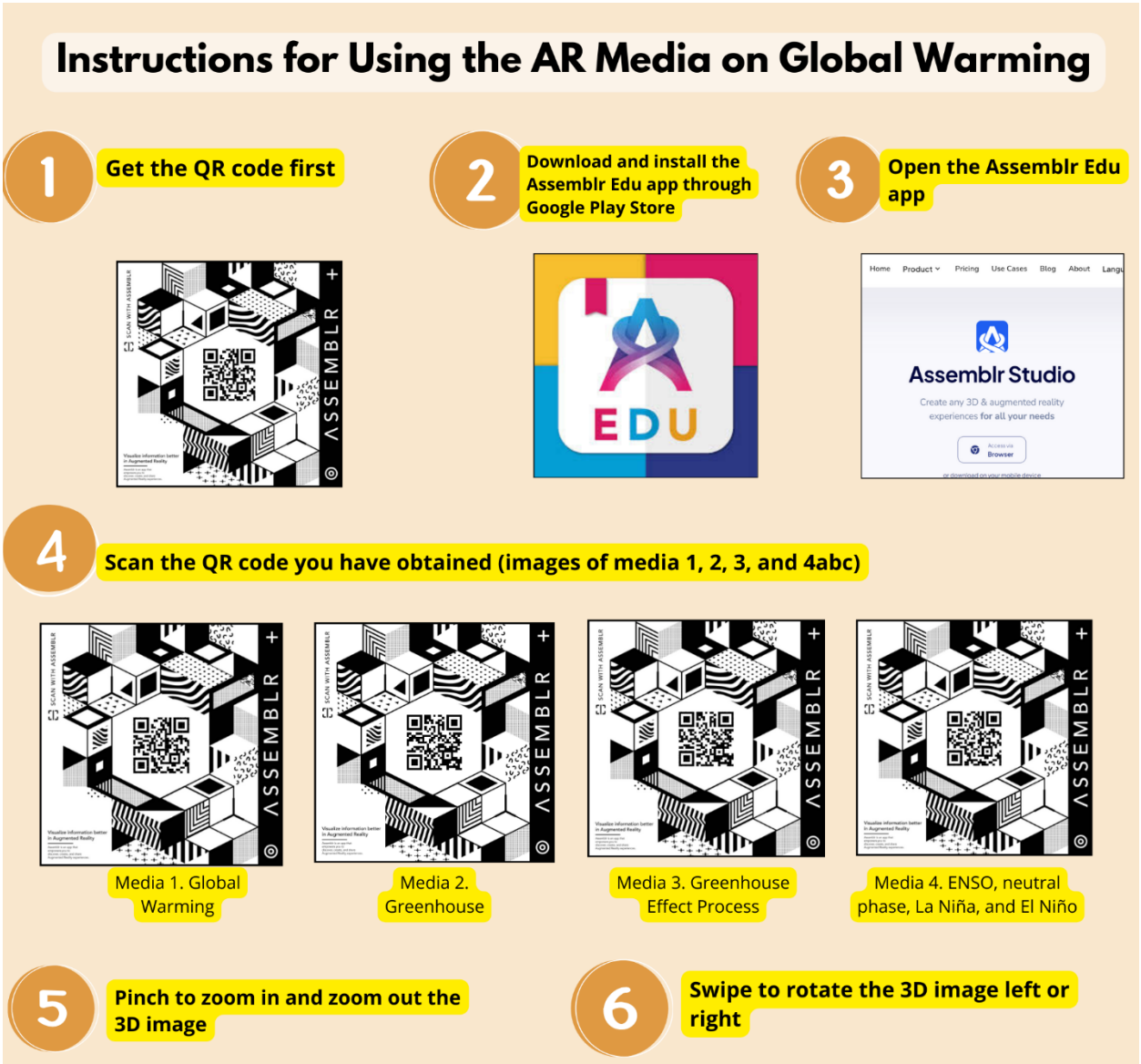
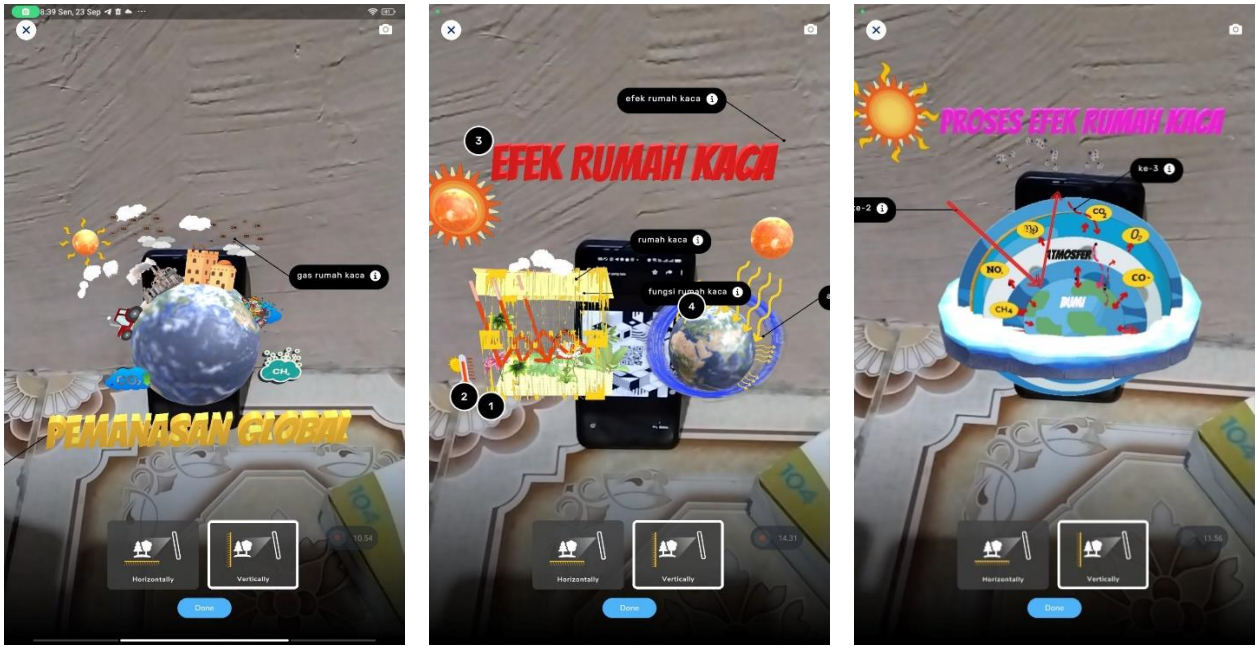


Figure 3. Instructions for using AR media on global warming and climate change

Figure 4 presents an analysis of the augmented reality media, consisting of four core topics. The first topic features a 3D Augmented Reality visualization of global warming, where students are provided insights into the meaning of global warming, the process of its occurrence, the causes of global warming, and the gases that play a significant role in the increase in Earth's temperature. The second topic includes a visualization of the relationship between the greenhouse effect and global warming, providing students with an understanding

of the meaning of the greenhouse effect and its connection to global warming. The third topic details the process of the greenhouse effect. The augmented reality media for this process includes a step-by-step visualization of the greenhouse effect, featuring 2D and 3D images as well as text. The text will appear after students press the provided instructions.

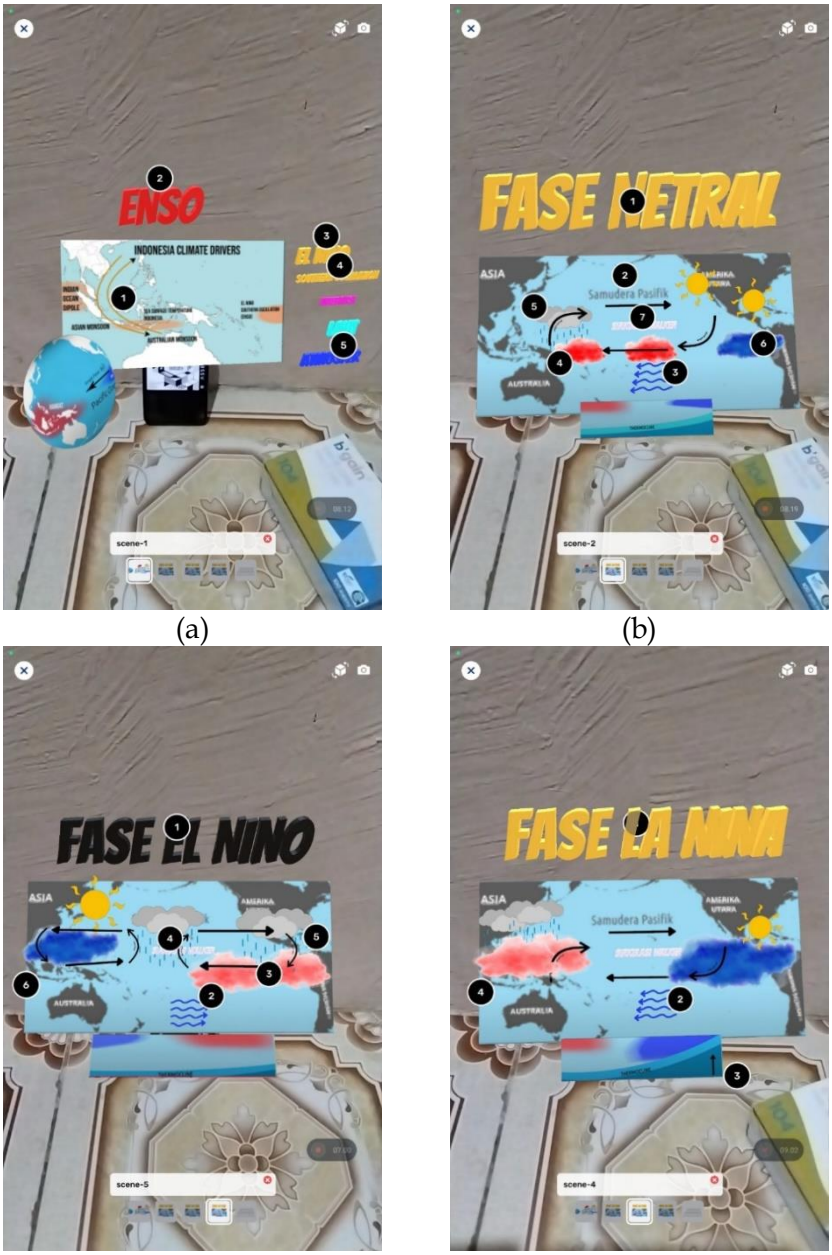


(a) (b) (c)

Figure 4. (a) Visualization of AR material on global warming; (b) Visualization of AR material on greenhouse effect; and (c) Visualization of AR material on the greenhouse effect process

The fourth topic contains four key materials related to climate change. Figure 5.1 displays 2D and 3D images, along with text visualizing the material on ENSO (El Niño Southern Oscillation). This material provides a visualization of the Pacific Ocean map and the two continents bordering it, highlighting that the ENSO process occurs due to changes in clouds, atmosphere, winds, and ocean conditions in the Pacific Ocean. Figure 5.2 presents material on the neutral phase of the Pacific Ocean, including visuals of clouds, sky, sea, and winds. Next, Figure 5.3 contains information about El Niño, detailing the processes involved in El Niño development in the Pacific Ocean and its impacts on Indonesia. Finally, Figure 5.4 illustrates the processes of La Niña in the Pacific Ocean and its effects on Indonesia.

Based on the results of the visualizations developed by the research team, there are notable differences compared to several augmented reality media developed by other researchers. The distinction in this paper lies in the combined development of augmented reality media focusing on global warming in relation to climate change. Previously, augmented reality media on global warming was developed by (Kholiq, 2020) which utilized media other than Assemblr Edu, while this study develops media using a different application or website, complemented by additional materials. In this article, several slides of global warming media have been developed, covering three main topics: global warming, the greenhouse effect, and the processes involved in the greenhouse effect. Simultaneously, augmented reality media for climate change has been developed, consisting of four core topics: ENSO, the neutral phase, La Niña, and El Niño. The hope and objective of developing this AR media are for students to construct their knowledge accurately and to eliminate any abstract notions regarding global warming and climate change. Furthermore, students can grasp the urgency of the global warming issue, which is currently a focal point of international attention (Negi, 2024; Wibowo et al., 2024).



(a) (b)

(c) (d)

Figure 5. (a) Visualization of AR material on ENSO; (b) AR portrait of neutral phase material; (c) Visualization of AR material on El Niño phase; and (d) Visualization of AR material on La Niña

Augmented Reality Media Validation

The validation of augmented reality media on global warming and climate change has been assessed by three experts in media and earth sciences. The validation assessment instruments for augmented reality media were categorized into three indicators: alignment with the *Merdeka Belajar* curriculum, student interactivity, and understanding of concepts and benefits.

Table 2. Results of media validation for alignment with the *Merdeka Belajar* curriculum

No	Statement	Modus	Category Assessment	Percentage Assessment
Alignment with the *Merdeka Belajar* curriculum				
1	The Augmented Reality (AR) media on global warming	4.0	Very Good	100%

No	Statement	Modus	Category Assessment	Percentage Assessment
	and climate change is suitable for use in the *Merdeka Belajar* curriculum			
2	The topics used in the AR media on global warming are relevant to the material in the Merdeka Curriculum physics textbook for grade X	4.0	Very Good	100 %
3	The developed AR media aids in achieving the learning objectives for the material on global warming	4.0	Very Good	100 %
4	The developed media provides students with the freedom to explore their knowledge related to global warming	4.0	Very Good	100 %
5	The Augmented Reality media is interactive in presenting information about climate change	3.0	Good	75%
Average score of alignment with the *Merdeka Belajar* curriculum		3.8	Very Good	95%

Table 3. Results of student interactivity validation

No	Statement	Modus	Category Assessment	Percentage Assessment
Student Interactivity				
1	Students can interact directly with digital Augmented Reality objects, which helps enhance their understanding of concepts.	4.0	Very Good	100 %
2	Students are encouraged to utilize digital media for learning about global warming.	4.0	Very Good	100 %
3	Students are motivated to increase their knowledge related to technological advancements.	4.0	Very Good	100 %
4	Students are encouraged to use Augmented Reality for studying other subjects beyond global warming.	4.0	Very Good	100 %
5	Students show enthusiasm in projecting augmented reality media in the classroom for global warming material.	4.0	Very Good	100 %
	Average score of student interactivity	4.0	Very Good	100 %

Table 4. Results of validation on concept understanding and benefits

No	Statement	Modus	Category Assessment	Percentage Assessment
Concept Understanding and Benefits				
1	This AR media provides sufficient context to understand the relationship between human activities and global warming.	4.0	Very Good	100 %
2	The AR media on global warming clearly illustrates the greenhouse effect process.	4.0	Very Good	100 %
3	The Augmented Reality media depicts the relationship between global warming and the processes involved in the greenhouse effect.	3.0	Good	75%
4	The AR media motivates students to be more environmentally conscious.	4.0	Very Good	100 %
5	The AR media encourages students to care more about the environment.	4.0	Very Good	100 %

No	Statement	Modus	Category Assessment	Percentage Assessment
6	Average score of concept understanding and benefits	3.8	Very Good	95%

From the results in Table 2, Table 3, and Table 4, it is evident that the overall indicators for the validity assessment of the AR media achieved a score of 96%. This result is obtained from the average percentage of the three indicators. Therefore, the media developed by the researchers is suitable for implementation in a wider classroom setting. The materials used align with the current curriculum in schools, namely the *Merdeka Belajar* curriculum. This curriculum utilizes technology as a supporting tool to create more flexible, creative, and relevant learning experiences that meet contemporary needs. Furthermore, the integration of AR in literacy education on global warming not only facilitates students' understanding of this issue but also enhances the skills and knowledge necessary to tackle future challenges.

Students Prior Knowledge of Global Warming and Climate Change

The assessment instrument developed by the researchers consists of multiple-choice tests administered to 30 students from 6 classes. The sampling method used for analyzing students' prior knowledge in understanding global warming and climate change was random. After the test instruments were distributed and assessments were conducted, the results were analyzed using SPSS software for data processing. This test results involved analyzing the literacy knowledge of global warming and climate change concerning the scores of male and female students among the 30 participants. The analysis of the data obtained is presented in Table 5 (Dependent variable: students' initial scores).

Table 5. Descriptive statistics

Gender	Class	Mean	N
Male	X-1	81.50	2
	X-2	73.50	2
	X-3	68.00	1
	X-4	58.00	1
	X-5	68.50	2
	X-6	74.00	2
	Total	72.10	10
Female	X-1	77.33	3
	X-2	63.33	3
	X-3	56.75	4
	X-4	52.75	4
	X-5	54.00	3
	X-6	40.33	3
	Total	57.15	20
Total	X-1	79.00	5
	X-2	67.40	5
	X-3	59.00	5
	X-4	53.80	5
	X-5	59.80	5
	X-6	53.80	5
	Total	62.13	30

Table 5 shows that the average initial knowledge score of students on global warming and climate change for grade X is 62.13. This average indicates that the mean score of male students is higher than that of female students, with the average score for 10 male students being 72.10, while the average score for 20 female students is 57.15. The distribution of average scores for both female and male students across each class is detailed in Table 4. This difference may be influenced by the unequal number of male students, as the sample was taken randomly. Thus, this factor could also contribute to the observed disparity. Before conducting a significant difference test to analyze the mean differences, the assumption tests are presented in Table 6.

Table 6. Normality and homogeneity

Gender		Test of normality	Test homogeneity of variances
Students' Initial Scores	Male	0.200	0.121
	Female	0.097	
sig ≥ 0.05 homogeneity sig ≥ 0.05 normality			

Table 6 shows that the data obtained is normally distributed and homogeneous, allowing for the mean difference test to be conducted using ANOVA.

Table 7. One-way ANOVA test of students' initial scores by gender

Variable	F	Sig.
Students' Initial Scores* gender	7.12	0.013
sig ≤ 0.05 There is a significant difference in students' initial scores based on gender.		

Table 7 displays the ANOVA test results between students' scores and gender. The significance level (sig) obtained is less than 0.05, indicating a significant difference between the initial knowledge scores of male and female students when answering questions related to global warming and climate change. Significant differences in student knowledge analyses often arise due to several factors (Nadhifah & Jauhariyah, 2021; Sulisworo et al., 2021; Wulandari et al., 2021). For instance, analyses have shown that the profiles of male and female students differ significantly (Wulandari et al., 2019). One contributing factor is the characteristics of the material in relation to gender habits, although this cannot be used as a definitive reference. Similar patterns of difference have also been observed between genders, where males tend to exhibit a more technocentric attitude toward environmental issues, while females demonstrate a more ecocentric attitude (Hikmandayani et al., 2021; Tolppanen et al., 2022). In this analysis, the observed differences are due to the unequal sample sizes of males and females, which realistically should be equal, thereby affecting the results.

Table 8. One-way ANOVA test of initial knowledge scores across all classes

Variable	F	Sig
Students' Initial Scores* class	2.231	0.084

The significance level (sig) is ≥ 0.05, indicating that there is no significant difference in initial knowledge scores among the different classes.

Table 9. Post hoc ANOVA test for differences in scores between each class

Class		Mean Difference	Sig.	Class		Mean Difference	Sig.
X-1	X-2	11.600	1.000	X-4	X-1	-25.200	.165

Class		Mean Difference	Sig.	Class		Mean Difference	Sig.
	X-3	20.000	.581		X-2	-13.600	1.000
	X-4	25.200	.165		X-3	-5.200	1.000
	X-5	19.200	.697		X-5	-6.000	1.000
	X-6	25.200	.165		X-6	0.000	1.000
X-2	X-1	-11.600	1.000	X-5	X-1	-19.200	.697
	X-3	8.400	1.000		X-2	-7.600	1.000
	X-4	13.600	1.000		X-3	.800	1.000
	X-5	7.600	1.000		X-4	6.000	1.000
	X-6	13.600	1.000		X-6	6.000	1.000
X-3	X-1	-20.000	.581	X-6	X-1	-25.200	.165
	X-2	-8.400	1.000		X-2	-13.600	1.000
	X-4	5.200	1.000		X-3	-5.200	1.000
	X-5	-.800	1.000		X-4	0.000	1.000
	X-6	5.200	1.000		X-5	-6.000	1.000

The significance level (sig) is ≥ 0.05, indicating that there is no significant difference in initial knowledge scores among the different classes.

Table 8 shows that there is no significant difference in the initial knowledge scores of students on global warming across all classes. To further examine whether there are differences among each class, a post hoc analysis was conducted, as shown in Table 9. The overall results provide an overview of the score differences between Class One and the other classes. Thus, the analysis indicates that there are no significant differences in the initial knowledge test scores of students regarding climate change and global warming across the different classes. To illustrate the results of the initial knowledge tests by gender or by class, this information is presented in Figure 6.

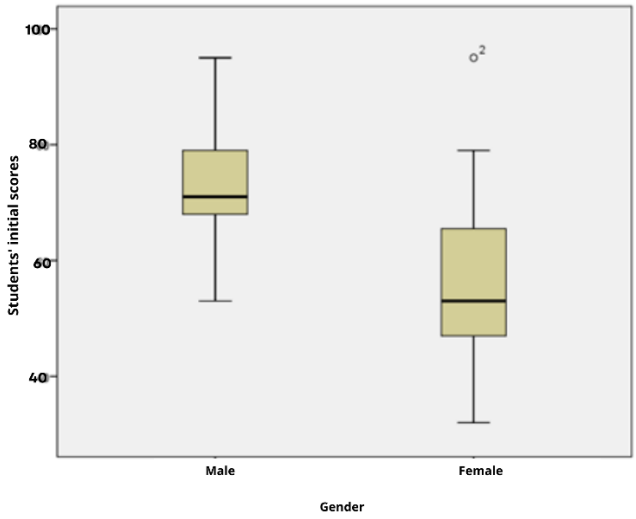


Figure 6. Boxplot and linear graph of students' initial scores by gender

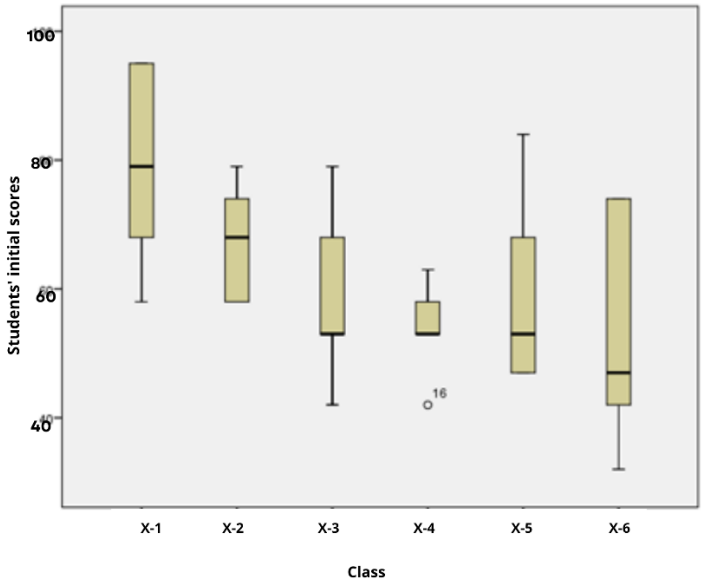


Figure 7. Boxplot and a line graph of students' initial scores by Class X

Figure 6 illustrates that the boxplot analysis reveals male students scoring higher than female students. The upper quartile range for male students is between 70-80, while the upper quartile range for female students is between 50-65. The highest score among male students is 81.50, whereas the highest score for female students is 77.33, as shown in Table 4.

Figure 7 displays a boxplot analysis on the left and a line graph analysis on the right. Both visuals indicate that the highest average score is obtained by Class X-1, while the lowest score is seen in Class X-4. Class X-1 outperforms the other classes because the grouping of students has been aligned with their foundational abilities. The school's classification starts with Class X-1 (with very superior foundational abilities), followed by Class X-2 (superior foundational abilities), and Class X-3 (average foundational abilities).

This analysis aligns with the data, as the initial ability test scores in global warming and climate change show that Class X-1 consistently achieves higher scores, followed by Class X-2. According to (Wang et al., 2023) , grouping classes by ability provides numerous benefits. Higher-performing classes tend to be accustomed to receiving more tasks and instructions, leading to students who are diligent and meticulous in their studies, possess higher motivation, and demonstrate strong collaboration and emotional intelligence(Carnoy & Rodrigues, 2024; Hemi et al., 2024; Hermann et al., 2024), Consequently, the treatment provided differs from that in classes with average-performing students (Blanco-Varela et al., 2024; Park, 2024). Thus, the data analysis confirms that Class X-1, being a superior grouping, has a more advanced understanding compared to the other classes.

CONCLUSION

Based on the research analysis, the development of augmented reality media for the topics of climate change and global warming has progressed well, as demonstrated by the procedures followed in the development process and the completed media showcased in the documentation. The overall validation results for the augmented reality media achieved an excellent rating across three assessment indicators. Additionally, the analysis of students' initial knowledge scores in climate change and global warming revealed a significant difference between male and female students, while no significant differences were found among the different classes. However, classes grouped by performance levels showed higher average scores compared to the others. Future research should focus on analyzing students' scores after

the implementation of augmented reality media for climate change and global warming. This analysis will help assess the effectiveness of the media in enhancing students' understanding and knowledge retention of these critical topics.

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