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Development of Augmented Reality-based Interactive Learning Media to Increase Interest in Environmental Education

Desy Safitri[1], Arita Marini[2], Annisa Fitri Auliya[3], Sujarwo[4], Prayuningtyas Angger Wardhani[5]

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ABSTRACT

Purpose This study aimed to determine the effect of interactive learning media based on Augmented Reality through the Assemblr EDU application on increasing fourth-grade students' interest in environmental education in the material plants parts and their functions. **Methodology** This R&D approach was used to conduct this research study. The sample of this study comprised 100 Grade-IV students in Pondok Aren District, Province of Banten, Indonesia. This study used a *one-group pretest-posttest* experimental research technique. The research instrument was a *pretest* and *posttest questionnaire.* The data analysis carried out in this study was inferential analysis with the t-test. **Findings** The study concluded that the use of interactive learning media based on Augmented Reality through the Assemblr EDU application positively impacted students' interest in environmental education. **Implications to Research and Practice** This research can contribute to the school by increasing student attentiveness to be engaged in environmental education so that the students can assimilate the teaching material constructively.

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[1] Universitas Negeri Jakarta, Indonesia. Email: desysafitri@unj.ac.id,
ORCID ID: https://orcid.org/0000-0001-8018-1136
[2] Universitas Negeri Jakarta, Indonesia. Email: aritamarini@unj.ac.id,
ORCID ID: https://orcid.org/0000-0002-4947-996X
[3] Universitas Negeri Jakarta, Indonesia. Email: ftrauliya2425@gmail.com,
ORCID ID: https://orcid.org/0009-0008-3800-4070
[4] Universitas Negeri Jakarta, Indonesia. Email: sujarwo-fis@unj.ac.id,
ORCID ID: https://orcid.org/0000-0002-1809-1663
[5] Universitas Negeri Jakarta, Indonesia. Email: prayuningtyasangger@unj.ac.id,
ORCID ID: https://orcid.org/0000-0002-0216-3765

Introduction

Environmental education is crucial for students because it can prepare them to become individuals responsible for their ecology and environment. If students are well-versed in ecological education, it can increase their knowledge about updated environmental issues so that they can identify environmental problems and find alternative solutions. Ecological education can also form a caring and responsible attitude in treating and protecting nature. Furthermore, ecological education can develop students' awareness and encourage them to change their behaviour to be environmentally friendly. By studying ecological education, students can become agents of change who play a role in protecting and preserving the environment. Various ways are done to overcome environmental damage, not only by making technical efforts but also by educative, informative, and persuasive efforts, such as the use of learning media in Augmented Reality-based environmental education, so that students know and understand more deeply about the environment.

Environmental education significantly influences environmental awareness, lifestyle, and daily behaviour. The need for higher education to integrate environmental education shows a strong relationship between the intensity of environmental education and environmental knowledge. Environmental education plays a role in instilling positive values, strengthening existing values, and developing skills towards the environment. Environmental materials integrated into learning are essential for students to understand attitudes and behaviours towards the environment. Studies have stated that there is a convergence between environmental science and education (Wals et al., 2014). Environmental problems cannot be solved by science alone but also through environmental education, which instils values and environmental ethics and changes behaviour. Another study (Zsóka et al., 2013) states that greening is due to environmental education, namely environmental knowledge, attitudes, consumer behaviour, and pro-environmentalism in students and college students

Moreover, the rapid development of technology in the current era of globalization has excellent benefits in various fields of life, one of which is the field of education. Technological assistance in education can support the learning process, making it easier for students to access knowledge quickly and easily and package it more attractively through technology-based interactive learning media. Using technology in learning through interactive learning media is one of the solutions to answer learning problems in Indonesia, especially for elementary school students to understand abstract concepts. One of the problems is that students often need to read and understand the concepts behind books that contain much text and few illustrations, thereby reducing students' interest in participating in learning.

Augmented Reality (AR) is a form of virtual visualization combined with physical, real-world information, which has been helpful for learning performance, motivational factors, and attitudes in different educational settings (Krüger, Palzer, & Bodemer, 2022). AR can support student motivation and is suitable for learning (Karagozlu et al., 2019). Romalee et al. (2023) stated that Augmented Reality links theoretical explanation and practice, which entails interaction on collaboration and autonomy in the teaching and learning process, allowing interactive and self-learning, laboratory cooperation and practice from other students without teacher assistance. Augmented Reality thus plays a vital role in

explaining things that happen in the laboratory. In laboratory learning, students are involved in the learning process faster and learn more when something interests them (Boukayoua, Kaddari, & Bennis, 2021). In the learning process at school, many teachers focus more on delivering subject matter and only ensure that students can receive knowledge but pay less attention to students' interest in understanding the material. Students sometimes consider subjects problematic because they have many abstract concepts and train students to reason and improve communication skills and creative thinking (Ruiz-del-Pino, Fernández-Martín, & Arco-Tirado, 2022).

Furthermore, Augmented Reality enhances life by using knowledge and facing an increasingly technological world (Buchner & Kerres, 2023). This makes it a challenge for teachers to be able to create exciting learning strategies to increase students' interest. Making learning more effective and encouraging students to participate actively requires using learning media. Augmented Reality (AR)-based media in learning is an example of suitable technology to increase student readiness in understanding learning material (Grodotzki, Müller, & Tekkaya, 2023). Therefore, choosing such learning media that suits students' interests and keeps them from being left behind by the times is necessary. Besides that, AR can also overcome abstract material concepts to become more concrete (Karagozlu et al., 2019). Thus, the application of interactive media based on Augmented Reality is expected to make it easier for students to accept and understand learning material so that it is possible to increase student interest in learning, especially in environmental education, such as material explaining plants parts and their functions.

There is a dearth of research studies on Augmented Reality-based interactive learning media to increase students' interest and motivation in environmental education. Previous research has paid limited attention to Augmented Reality as an effective tool for students to use it as a learning medium (O'Connor & Mahony, 2023). The effectiveness of using Augmented Reality in learning as being capable of increasing students' learning motivation, to give better learning outcomes, has not been studied so far, as students still use traditional methods. Making interactive learning media based on Augmented Reality is something new for students, which will encourage students' curiosity; this curiosity has a positive and significant relationship with interest in learning (Chang et al., 2022). Many studies explain the role of Augmented Reality in education, but only a few discuss the role of Augmented Reality in increasing student interest in learning. For the delivery of subject matter with abstract concepts, such as environmental education, to be easily conveyed and understood by students, interactive learning media is needed. Therefore, this study aims to develop interactive learning media based on Augmented Reality to study plants parts and their functions.

In order to fill this research gap, this research has therefore focused on students' experiences using interactive media based on Augmented Reality to increase students' interest in environmental education in Grade-IV. The core question of this research is, "Will the use of interactive learning media based on Augmented Reality impact increasing students' interest in learning?". There are other problem formulations in this study, including: (1) How is the design of interactive learning media based on Augmented Reality? (2) How does interactive learning media based on Augmented Reality influence students' interest in environmental education?

This research developed learning media using an Augmented Reality application, Assemblr Edu, which can be accessed via a mobile phone or laptop. The study discussed the use of Assemblr EDU in education, including its influence in increasing student interest in learning. This study cited a few empirical studies relevant to the topic, up-to-date, and comprehensive to answer the problems that exist in the research. In this literature review, analysis, synthesis, and critical evaluation have been carried out to get a clear picture of the topics discussed and provide an appropriate overview of the current situation. This study also combined environmental education through Augmented Reality for students to transmit information and internalize and understand environmental material integrated into learning. This study highlighted that through Augmented Reality, the students become motivated and their interest gets stimulated, and they can develop their understanding of environmental material cases.

In addition, the students can also learn how to understand environmental material cases contextually and interestingly through Augmented Reality. They can experience real life activities, extended with virtual elements, such as visiting places where environmental cases are located. This enriches the learning experience and provides access to students needing help visiting such places. Additionally, users can create and interact with virtual objects in the real world, opening up opportunities for broader exploration and creative expression. This can provide an experience that creates high engagement and allows individuals to explore new ideas. Furthermore, students can take attitudes and skills to respond to these environmental materials. This will result in an integrated innovation model between environmental materials integrated into learning with Augmented Reality to create a young generation who are aware, concerned, and responsible for the environment, and will increase environmental literacy.

Literature Review

- *Environmental Education*

Environmental education is provided both formally and informally by mastering ecological concepts, increasing the ability to think critically, creatively, and innovatively, and aligning attitudes and ethics related to environmental problems. Environmental education can be renovated by synergizing various environmental materials integrated into social studies learning through Augmented Reality so that environmental materials can be transmitted on target and contextualized, informative, engaging, and fun to improve students' positive attitudes towards the environment. A study states that a strong attitude towards nature and the environment will result in positive behaviour towards the environment (Roczen et al., 2013). A person's behaviour can be predicted by knowing his attitude. A person's propensity to behave can also be determined by his or her attitude. One study stated that environmental education can directly benefit the environment and address concrete conservation issues by developing and enhancing environmental attitudes, values, knowledge, and building skills that prepare individuals and communities to take positive environmental action collaboratively (Ardoin, Bowers, & Gaillard, 2020).

Environmental education provided in learning can build competencies and skills in helping students adopt positive behaviours towards the environment (El Moussaouy,

Abderbi, & Daoudi, 2014). Environmental education can improve students' environmental knowledge, such as participation and holistic environmental understanding (Fokides & Chachlaki, 2020). Environmental education can raise awareness so that students become environmentally literate about the harmful effects of plastic waste and the importance of environmental conservation, where environmental education becomes a central point where humans can learn the importance of nature and their friendship with the earth (Charatsari & Lioutas, 2018). Environmental education can improve environmental literacy through the role of nature reserves in protecting and sustaining natural resources (Dong.Z et al., 2024). Environmental education increases understanding of complex ecological processes and the role of humans in environmental change. Through an interdisciplinary approach, environmental education encourages students to be more critical and practical with the concept of sustainable development so that students can develop a more holistic appreciation of the environment (Johns & Pontes, 2019).

Another study showed that environmental education through an interdisciplinary approach encourages students to be more critical and practical with the concept of sustainable development so that students can develop a more holistic appreciation of the environment (Walshe, 2017). Environmental education can improve students' understanding of the environmental, social, and economic dimensions of sustainability, where environmental education teaches respect for biodiversity and manages the socialization of good ecological knowledge to students. Another study suggests that education for Sustainable Development (ESD) largely emerged from the Environmental Education (EE) model to teach how actions for 'development' positively and negatively affect our society and the rest of nature, to determine how such actions can be 'sustainable' without causing future socio-environmental flows or oppression (Misiaszek, 2019).

Environmental education can promote environmentally friendly practices by using teacher strategies and approaches to integrating plastic resource education into school life (So & Chow, 2019). Teachers overcame barriers by using different strategies to increase students' engagement in environmentally friendly behaviours and gaining support from stakeholders related to school management and parents.

- *Augmented Reality*

In the current global era, technological developments have an impact on the field of education. Technology in education provides learning using visual and audio media, which is very friendly to the student learning environment and has easy access to information. It has been argued that using technology improves student academic success, provides student-centred education, and effectively attracts attention (Silva, Bermúdez, & Caro, 2023). One of the technologies that can be used in visual learning is Augmented Reality. Augmented Reality is a contemporary visualization technology that expands sensory perception through digital objects (Karagozlu et al., 2019). Expansion of sensory perception can stimulate students to attract their attention to learning. Forms of Augmented Reality technology are hardware and software capable of combining images, text, video, sound and animation in 2D or 3D form, displayed virtually on top of the natural environment captured by the camera in the device (Yang, Lai, & Wang, 2023). Augmented Reality can make learning more varied and allow us to adapt to the times.

Augmented Reality is believed to enhance learning with interactive and fun experiences (Krüger et al., 2022). This happens when students get interactive learning experiences using Augmented Reality, which combines virtual elements with elements in the real world to create new methods of delivering material and become more attractive. Besides being an exciting learning medium, Augmented Reality has easy access because it can be used via computers, tablets and smartphones, so it is suitable for elementary school students. Currently, there is much software based on Augmented Reality, and of course, it has been adapted to the needs of students, especially elementary schools, with attractive appearance and features. One of them is the mobile Augmented Reality application that is often used, the Assemblr EDU application. This platform is a combination of Lego and Pokemon GO. Assembly is designed to help users create 3D content visualized in Augmented Reality. The results can be placed in the real world for everyone to access (De Lima, Walton, & Owen, 2022). The Assemblr EDU application makes it easy for teachers to create interactive learning media and does not need to pay much money.

Augmented Reality can be an alternative technology that will enhance the learning process, motivate students and provide a paradigm shift in future learning. Augmented Reality as an interactive learning medium can provide exciting learning experiences to students, especially for lessons with abstract concepts. Using interactive learning media based on Augmented Reality can also support students in being more involved in the learning process, increasing their motivation to learn.

- *Student Learning Interest*

Interest is a desire and can be considered someone's liking for something. Interest is one aspect that influences student achievement (Lee & Boo, 2022). Thus, increasing student interest in learning is needed. Interest in learning has indicators in it, namely the feeling of being interested and also happy to learn, the existence of active participation, the tendency to pay attention and excellent concentration, having positive feelings and a willingness to learn, which continues to increase, the existence of comfort when learning. It can decide his learning process (Sparfeldt & Schwabe, 2024). In the process, students' interests are not always influenced by internal factors, namely the students themselves, but can also be influenced by external factors, such as teachers (Yarahmadian, Oroji, & Williams, 2022).

The teacher plays a vital role in the learning process in the classroom to create a comfortable and not dull learning environment. The use of technology-based interactive learning media can be one of the efforts of a teacher to attract students' interest in the learning process. Technology-based interactive learning media can make abstract subject matter more concrete by displaying visual material such as video, animation, and Augmented Reality. In addition, using technology in learning will make it easier for students to access the subject matter provided to be studied anytime and anywhere so that it will support a more effective and efficient learning system. This study aims to understand whether interactive learning media based on Augmented Reality through the Assemblr EDU application in learning material parts and functions of plants will increase students' interest in learning in class IV of elementary school (Zhou, 2022).

Method

- *Research Design*

This research used a pre-selected subject population to develop interactive learning media based on *Augmented Reality* and evaluated its effectiveness. The test was carried out twice before and after the experimental treatment in this design. The pretest was given first, and the next step was to use the Augmented Reality application in the sample. After the teaching intervention, a posttest was conducted, and the results were finally measured. As for the pattern of the one-group pretest-posttest research method, Pretest (O_1), treatment (X), and posttest (O_2) can be seen in Table 1.

Table 1

Experimental Research Design

Group	Pretest	Treatment	Posttest
Experiment	O_1	X	O_2

Notes:
O_1: Pretest
O_2: Posttest
X: *Augmented Reality*-based interactive learning media.

The use of one group in this study was used because it can see the changes that occur after treatment or intervention. The pretest was used to measure the understanding or initial condition of the subject before the treatment was carried out. Meanwhile, the post-test measured changes after the subject had experienced treatment. By comparing pretest and post-test scores, researchers could evaluate the effectiveness of the development carried out where all subjects were in the same group. This allowed the researcher to control outside variables affecting the study results. By using only one group, differences between different groups could be eliminated.

- *Population and Sample*

This research was conducted in June to Sept, 2023 at Pondok Aren District Elementary School, South Tangerang City, Indonesia. The population in this study were fourth-grade students at SDN Pondok Aren, Province of Banten, Indonesia. In this study, 100 Grade-IV students at SDN Pondok Aren 02 District, Province of Banten, Indonesia were used as subjects. A simple random sampling technique was used to identify the sample. This sampling technique used the Slovin formula to obtain a sample size of 100 fourth-grade students. This study used an experimental research method with a one-group pretest-posttest. In addition, the researcher used the paired sample t-test to test the hypothesis and the Kolmogorov-Smirnov t-test to test normality in this study.

- *Data Collection Instruments*

The data collection technique in this study used a non-test technique, which was carried out using a questionnaire. This questionnaire contained questions that have been prepared in the form of pretest and posttest. Pretest and posttest were provided to determine the results of the intervention using the AR application. Data were analyzed using descriptive statistical methods, and the

t-test was used to test whether the mean values were significantly different before and after the intervention. Table 2 and Table 3 display the items in the pretest and posttest questionnaires.

Table 2

The Items of The Pretest Questionnaire

No.	Items
1.	Students' knowledge of Augmented Reality
2.	Previous use of Augmented Reality technology in classroom learning
3.	Advantages of using Augmented Reality in learning compared to other media
4.	The belief is that the use of Augmented Reality learning media can increase interest and motivation in learning about the environment.
5.	Your level of understanding of environmental concepts before using Augmented Reality learning media
6.	Your level of understanding of environmental concepts before using Augmented Reality learning media
7.	Difficulty learning about current environmental materials
8.	Students' preference in using virtual reality media to help learning
9.	The learning process has been carried out in education so far.
10.	Difficulties during the learning process of environmental materials
11.	The way teachers explain environmental material in classroom learning
12.	Experiences of difficulties in understanding environment-related materials with conventional media
13.	The use of Augmented Reality media in improving the understanding of concepts that are difficult to understand abstractly
14.	Students' opinions about the use of virtual reality media in the learning process
15.	Augmented reality media is an exciting media in explaining environmental material

Table 3

The Items of The Posttest Questionnaire

No.	Items
1.	Use of Augmented Reality to enrich learning experience outside the classroom
2.	Students actively participate in learning by using Augmented Reality.
3.	Challenges faced in implementing Augmented Reality in the classroom
4.	Advantages and disadvantages of using Augmented Reality as learning media in the classroom
5.	The role of teachers in integrating Augmented Reality in classroom learning
6.	Augmented Reality can improve students' learning experience.
7.	The use of Augmented Reality can improve conceptual understanding of environmental education materials.
8.	Level of interest and motivation in learning about the environment after using Augmented Reality learning media
9.	Students' responses after using Augmented Reality in learning (more fun or helps understand the material about the environment)
10.	Strategies to optimize the use as a practical learning media
11.	The use of Augmented Reality helps students understand environmental concepts.
12.	Augmented reality learning media makes students more active and involved in the learning process.
13.	Augmented Reality makes learning materials about the environment more exciting and relevant to students.
14.	Augmented Reality can help students understand abstract and complex concepts.
15.	What is the potential impact of using Augmented Reality in learning in the future?

- *Data Analysis*

The normality test was performed using the Kolmogorov-Smirnov formula by Asymp's rules for scores before and after the test at a 5% alpha significance level. The basis for deciding on the normality test is: (1) If the significance value is > 0.05, then the residual value is normally distributed; (2) If the significance value is <0.05, the residual value is not normally distributed. The homogeneity test is carried out after the normality test, which is carried out on the pretest and posttest scores. The paired sample t-test was used. SPSS was used for data analysis.

Results

- *Design of Augmented Reality-based Interactive Learning Media for Material Parts and Functions of Plants*

Based on the information collected about plants parts and their functions, this Augmented Reality model was installed in the system via the Assemblr EDU application. The Assemblr EDU application can be accessed using a smartphone or tablet by scanning an image via a QR Code, and there are several other learning activities to learn material about plants parts and their functions, for instance, development of materials for plants parts and their functions using interactive learning media based on Augmented Reality. Researchers make interactive learning media based on Augmented Reality using the Assemblr EDU application or the website https://studio.assemblrworld.com/profile-completion. Applications and websites can be accessed free of charge to create Augmented Reality media in QR form. In preparing the material, the researcher collected information about plants parts and their functions through the 2013 curriculum student books. Several templates were used in storyboards in which there were many choices of characters and 2D and 3D objects that can be used to clarify material illustrations. However, some characters and objects were not accessible.

Storyboards in interactive learning media based on Augmented Reality contained mutually continuous scenes. Starting from studying the material of plants parts and their functions, an explanation of the parts of plants and their functions, as well as learning videos to clarify the material. Before publication, users can fill in information from the project by filling in the title, description of the material and the Augmented Reality media made, and the category according to the material's content. Once published, users can choose their appearance using a QR code that can be scanned through the Assemblr EDU application. The Assemblr EDU application can be installed via the Play Store or App Store.

Figure 1 is a product display scanned via QR or a link on the Assemblr EDU application. There are various buttons with different uses; button information can be seen on the icon in Figure 2. This button information can make it easier for students to understand how interactive learning media based on Augmented Reality works. In addition to button information, Figure 3 presents the material information containing the Material Name, Class, Theme, Basic Competency (KD), and learning objectives students must achieve using this interactive learning media. This scene has a menu page with a main menu button, which directly accesses the main menu page.

Figure 1. *Main Page of Learning Media Plant Parts and Their Functions*

Figure 2. *Information Button Page*

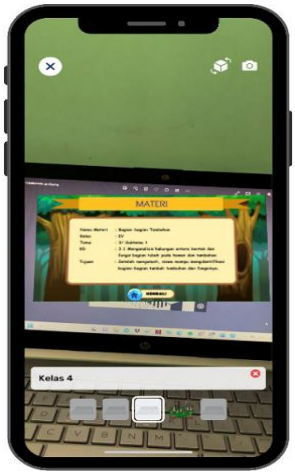

Figure 3. *Material Information Page*

Figure 4 shows the material page; on this page, students can clearly know the parts of the plant by pressing the number buttons attached to the tree parts. After pressing the number, an explanation of the plant parts and their functions are displayed, as shown in Figure 5. Students can zoom in and out of the AR display to clarify images of plant parts.

Figure 4. *Material Page of Plant Parts and Their Functions*

Figure 5. *Explanation Page for Plant Parts and Their Functions*

Figure 6. *Learning Video Pages of Plant Parts and Their Functions*

Figure 6 presents how students can watch learning videos about plant parts and functions connected to YouTube. The use of this video aims to make it easier for students to

understand material about plant parts and their functions. Then, students can select the "home" button to return to the start page.

- *Effect of Using Augmented Reality-based Interactive Learning Media on Students' Interest in Environmental Education*

Table 2 exhibits changes in students' interest before and after using Augmented Reality-based interactive learning media. In the Kolmogorov-Smirnov normality test, the Asymp criterion was applied with an alpha significance of 5%. The data is said to be normal if p > 0.05. As shown in Table 2, which presents the Kolmogorov-Smirnov normality test data for 100 students in the Pondok Aren sub-district).

Table 2

One-Sample Kolmogorov-Smirnov Test

One-Sample Kolmogorov-Smirnov Test		
N=100		Unstandardized Residuals
Normal Parameters	Means	.000
	Std. Deviation	5.594
Most Extreme Differences	Absolute	.080
	Positive	.068
	Negative	-.080
Test Statistics		.080
asymp. Sig. (2-tailed)		.113

Based on the Kolmogorov-Smirnov normality test findings, the researchers achieved a significant p-value of 0.113 > 0.05. The pretest and posttest data have a significance greater than 0.05; this indicates that H1 is acceptable. The pretest and posttest data are normally distributed and are parametric.

Table 3

Variance Homogeneity Test

Levene Statistics	df1	df2	Sig.
.050	1	198	0.823

Levene's homogeneity test was carried out using df1 = 1 and df2 = 198, and the results were significant based on the average, namely the significance value based on the average, namely 0.823 (Table 3). The hypothesis of the variance test is as follows:

H0: *All variants are the same or homogeneous*

H1: *All variants are not the same or not homogeneous*

If the p-value > 0.05 (5%) then H0 is accepted; H1 is rejected
If the p-value <0.05 (5%) then H0 is rejected; H1 is accepted

Because the difference in the significance value of 0.823 indicates greater than 0.05 and the data analyzed shows the same variance, it can be assumed that H0 is accepted

(homogeneous). This data is normal and homogeneous according to the normality and homogeneity test results. The Paired Samples T-Test method then evaluates the efficiency of the product using rheumatism statistics.

Table 4

Paired Sample Statistics

		Means	N	Std. Deviation	Std. Error Means
Pair 1	Pretest	43.2700	100	6.01657	0.60166
	Posttest	65.1400	100	6.06367	0.60637

Table 4 shows descriptive statistics for the One-Group Pretest-posttest design. The data shows an average difference in the pretest and posttest interest in environmental education. The average pretest shows 43.27, and the posttest shows 65.14, which means there is an increase in learning interest after using interactive learning media based on Augmented Reality.

Table 5

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Means	Std. Deviation	Std. Error Means	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Pretest - Posttest	-21.870	6.693	.669	-23.198	-20.541	-32.674	99	.000

The significance value in the data in Table 5 shows 0.000, which means it is smaller than 0.05. This shows that H0 does not affect increasing interest in environmental education before and after using interactive learning media based on Augmented Reality; otherwise, it is rejected. H1, the effect of increasing interest in environmental education after using interactive learning media based on Augmented Reality, is accepted.

Table 6

Effectiveness Test

	Pretest	Posttest		
Amount	43.23	65.14	N-Gain Score	N-Gain Score (%)
Average	43.27	65.14	0.43	43.50
Less effective				

Table 6 shows the N-Gain score test to see effectiveness. The data shows the value acquisition and n-gain categories in percentage. Based on the table above, the N-gain in the value category shows 0.43, which is included in the medium category, and the n-gain percentage shows 43.50.

Discussion

The study makes it evident that the renewal of environmental education can be done by synergizing various environmental materials integrated into learning through Augmented Reality for the formation of environmental students, where environmental material is visualized through abstract concepts for a more detailed understanding, thus making learning informative, engaging, and not dull in the formation of student characters who have a positive spirit towards the environment. Furthermore, students can visualize abstract concepts for a more detailed understanding, thereby increasing the absorption of information received by students, not saturated and dull, and more exciting and imaginative, which in turn occurs the cultivation of values, strengthening of values, and the resulting skills in responding to the environment are more optimal. The objectives of environmental education in learning become right on target by the learning objectives that have been set.

The results of this study can expand to complement existing research results. Previous research stated that in the learning process, the use of interactive learning media based on Augmented Reality can improve students' conceptual understanding (Aranda-García et al., 2023). In addition, providing new experiences for students using interactive media based on Augmented Reality can help them improve their analytical skills and make learning more attractive (Kovoor, Gupta, & Gladman, 2021). Student interest in the learning process is obtained from media designs characteristic of elementary school students, such as using animation, choosing bright colours, and learning media that are easily accessible and can be used anywhere and anytime.

The learning process that utilizes Augmented Reality technology as a learning medium has a positive impact on improving spatial visualization skills and student interest; this creative visual experience can be used to solve abstract problems for students because students can actively explore independently and create complex learning experiences and varied (Cheng et al., 2018; Eldokhny & Drwish, 2021; Nasongkhla, Chanjaradwichai, & Chiasiriphan, 2019). Thus, Augmented Reality can help students learn abstract subject matter to become more concrete.

Technology in education is very beneficial for teachers and students in creating an active learning process and can improve students' cognitive skills in understanding subject matter. Augmented reality technology in learning can produce new experiences in obtaining material because it combines subject matter with virtual and real-world elements around students to increase student interest and motivation in learning.

This research implies that Augmented Reality can increase students' interest in learning environmental education because it combines the virtual world that can increase students' imagination with the natural world in real time. Furthermore, students can see the honest and direct situation and imagine the results of the learning process provided by the teacher. Moreover, it stimulates students' mindset to think critically about problems and events in everyday life related to environmental problems.

Although Augmented Reality can offer an immersive learning experience, there are limitations to the scope of learning that Augmented Reality can reach, such as there is no quality and relevant Augmented Reality learning content available or there are concepts or

learning materials that may be difficult to realize in the form of AR or require a level of complexity that is difficult to represent. As a learning medium, it requires devices supporting Augmented Reality technology, such as smartphones, tablets, or specialized devices. Not all students or educational institutions may have access to such devices, which may hinder the widespread implementation of Augmented Reality. In addition, in this learning using Augmented Reality, the teacher is not only a teacher but also a facilitator, motivator, guide, and activity organizer, as well as assessment and feedback, who has an important responsibility to ensure effective and maximum learning through the use of Augmented Reality as an innovative learning tool.

For further research on the use of Augmented Reality, attention may be given to specific learning contexts, such as subjects, education levels, and target students, so that the use of Augmented Reality that is appropriately tailored to the needs and characteristics of students can increase its effectiveness, for example by developing Augmented Reality for people with disabilities to help understand the subject matter through meeting their limitations. Furthermore, the ethical considerations of the use of Augmented Reality include aspects of equality and accessibility. It is essential to ensure that this technology is accessible to all students, including students with special needs, and also to provide accessibility options, such as support for the use of hearing or visual aids, safety, and health.

The use of Augmented Reality can involve physical interaction with virtual objects that need to be considered in ensuring the safety of students when using this Augmented Reality; appropriate material content, where the content of the material created must be by ethical and moral values and learning objectives in the classroom so that it can provide educational value that is beneficial to students.

Conclusion

This study aimed to develop interactive learning media based on Augmented Reality by increasing the interest of fourth-grade students in environmental education on plant parts and their functions. In data management, this study used a one-group pretest-posttest design with different average scores between the pretest and posttest; namely, the pretest was 43.27, and the posttest was 65.14. This showed an influence on the development of interactive learning media based on Augmented Reality in class IV students of the Assemblr Edu application. In the learning process, students actively and independently gained new learning experiences through interactive media that combined virtual and real-world elements. The results prove that using technology in the learning process can be an alternative way to make lessons more interactive and fun to attract students' interest in learning. For teachers, interactive media based on Augmented Reality can help explain material that is abstract and far from students' reasoning, making it easier to understand because they can carry out simulations linked to the environment around students.

Interactive learning media based on Augmented Reality is a medium for teachers to increase students' interest in learning at the elementary school level, especially in abstract subject matter. This technology-based interactive learning media research must also continue to understand better the impact of using Augmented Reality technology with the Assemblr EDU application in school learning.

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