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Ecoexplore Development through Augmented Reality on Ecosystem Topics to Improve Students' Visual Literacy

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ABSTRACT

Development of Ecoexplore (explore nature) through Augmented Reality *(AR) on ecosystem material to improve students' visual Literacy. In today's digital era, science learning requires an approach that is more interesting and closer to the real world of students. This research aims to develop an interactive learning media, Ecoexplore, based on* Augmented Reality *(AR), combined with an approach to exploring the natural environment, particularly focusing on ecosystem materials. The method used is Research and Development (R&D) with the ADDIE model. This media was validated by experts and tested on teachers and junior high school students. The validation results indicate that Ecoexplore is highly feasible to use, and the user response is also very positive. The findings show that using AR technology linked to students' real-life experiences can improve visual literacy and make the learning process more fun, interactive, and meaningful. Moreover, Ecoexplore encourages students to observe and analyze ecosystem components concretely, fosters curiosity, supports active participation, and strengthens connections between theory and practice in science learning.*

INTRODUCTION

As we enter the era of Society 5.0, the world of education is experiencing a paradigm shift towards using innovative technology to improve the quality of learning. One of the main demands of this era is the integration of digital technologies such as Augmented Reality (AR) in creating innovative and contextual learning experiences (Akbar & Djakariah, 2024). AR has great potential in presenting visual information interactively and in real-time, making it very suitable for science learning, such as ecosystems that require an understanding of spatial and systemic relationships. This technology allows students to explore objects in three-dimensional form and interact with the

learning content directly, making the learning process more engaging and easier to understand (Dewi & Sahrina, 2021).

The real conditions in the field indicate that the learning process in schools still relies heavily on conventional methods, such as lectures and textbooks. Ecosystem material is often conveyed only through two-dimensional images, which are less capable of representing the complexity of interactions between living things and their environment (Suherja et al., 2022). This situation is exacerbated by low technological literacy among educators as well as limited digital infrastructure, especially in non-urban areas. As a result, students have difficulty in understanding abstract concepts visually and experience obstacles in developing the high-level thinking skills required in the 2nd century (Tungka et al., 2024; Umam et al., 2024).

This condition creates a gap between the potential use of technology in education and the learning practices that occur. However, the independent curriculum and 21st-century learning principles emphasise the importance of mastering new literacy, including visual literacy, as the ability to understand, interpret, and evaluate information in visual form, such as graphs, diagrams, simulations, and digital visual models (Santoso & Siregar, 2024). Visual literacy is crucial in science learning because most science concepts involve spatial relationships and the visualization of complex systems. In the context of ecosystems, students need to develop the ability to understand the structure and dynamics of ecological systems by visualizing the relationships between biotic and abiotic components in the surrounding environment.

Based on the integration of technology, meaningful learning needs to be linked to the real context around students (Matanari et al., 2020). The approach of exploring the environment is a method that encourages students to observe, explore, and reflect on ecosystem phenomena directly from the surrounding living environment. This approach is oriented towards the active involvement of students with the real environment, allowing them to build a contextual understanding of concepts before these are reinforced through digital visualisation. The combination of an approach to exploring the environment and Augmented Reality (AR) technology provides a strong learning synergy, where hands-on exploration experiences can be connected with digital simulations to deepen students' visual and conceptual literacy in understanding ecosystem systems (Sekarini & Arty, 2019).

Augmented Reality (AR) is a technology that combines two- or three-dimensional virtual objects into a real environment, then displays them directly

(*real time*) so that users can see and interact with the virtual object as if it were in the real world (Toha & Panggayuh, 2024). Several studies show that Augmented Reality (AR)-based learning media can improve students' understanding of concepts and visual skills. For example, Augmented Reality (AR) has proven to be effective in learning anatomy and geometry (Nauko & Amali, 2021; Feoh & Cristyadi, 2018). However, Augmented Reality (AR)-based learning research and products that explicitly develop visual literacy in ecosystem materials are still minimal.

The urgency of this research arises from the need for learning media innovations that are not only interesting and interactive but also help students understand information visually and contextually, meeting the demands of the digital era. Amid rapid technological developments and the increasing complexity of global environmental problems, students need the ability to read, interpret, and understand scientific visual information. It enables them to think critically and play an active role in addressing ecological issues around them. Without learning innovations that are relevant and adaptive to technological developments, the gap between students' visual literacy abilities and technological advances will widen (Tyas et al., 2025). As a result, science learning risks losing its meaning as a means to foster scientific understanding and concern for the environment in daily life.

This research presents an innovation in interactive learning media, "*Ecoexplore*", based on Augmented Reality (AR), which is specifically designed to improve the visual literacy skills of junior high school students in ecosystem materials. Linguistically, *Ecoexplore* is derived from the word "*Eco*" (ecosystem) and "*Explore*" (explore or jelajah). *Ecoexplore* is a learning medium that explores the environment, helping users deeply understand the interconnectedness between ecosystem components through interactive and fun learning experiences. This media aims to improve visual literacy while encouraging students' active involvement in the learning process. An attractively designed learning process can respond positively to the learning activities (Anduweni et al., 2024).

One important aspect of correctly understanding learning media is mastering commonly used tools, methods, and techniques, enabling the development and application process to occur more effectively and efficiently (Yevira & Nasir, 2022). This medium not only presents a three-dimensional visualization of ecosystem components and processes, but also provides an interactive experience that allows students to explore, interpret, and connect ecological concepts visually and actively. The roaming approach is used to

relate students' real experiences in their surroundings to Augmented Reality (AR) content in the media *Ecoexplore*. Therefore, the purpose of this study is to develop and test the effectiveness of the *Ecoexplore* learning media approach in improving students' visual literacy competencies. It is an integral part of strengthening science learning that is relevant to the needs of the times.

RESEARCH METHODS

Methods

This research employs a Research and Development (R&D) approach using the ADDIE model to develop junior high school ecosystem learning media via the Assemblr Edu platform. This approach was chosen because it can create real solutions to a problem. Through this stage, it is hoped that the media produced is really appropriate and able to support learning effectively (Dewi et al., 2024). The research method uses the ADDIE development model, which includes five sequential stages, namely, analysis, design, development, implementation, and evaluation (Alam et al., 2025). The **Figure 1** is the flow of the ADDIE model development carried out by the researchers.

Research Respondents

During the analysis stage, we identified science learning needs, particularly in ecosystem materials, through observation and interview activities with teachers and students at SMP Negeri 2 Mayong in the odd semesters of the 2023/2024 school year. Phase *Development* was carried out by conducting a feasibility test on learning media *Ecoexplore*, which was validated by one media expert and one material expert. The next stage of *implementation* was carried out through a limited trial involving 10 grade VII students of SMP Negeri 2 Mayong, using learning media based on Augmented Reality technology combined with an approach to exploring the environment.

Data Collection

The data collection techniques used were interviews and questionnaire distribution. The instruments used are validation instruments of media experts and material experts. There is a grid of media expert validation instruments compiled based on several assessment aspects, namely visual appearance, interactive design, technological suitability, media stability, and aesthetics.

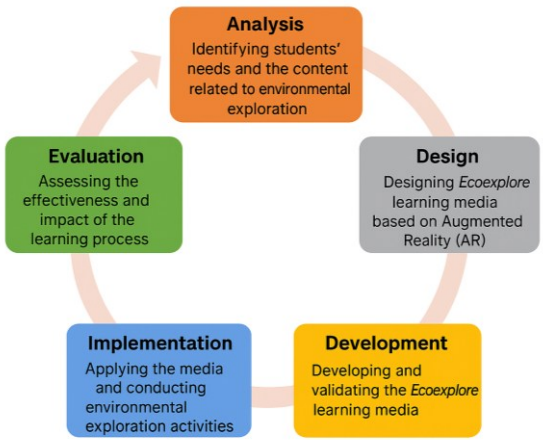

Figure 1. ADDIE Model Development Pipeline

The visual display aspects include indicators of colour suitability, layout, icons, and typography. The interactive design aspect assesses the ease of navigation and the use of Augmented Reality (AR) features in the media. The technology aspect focuses on the application's compatibility with a wide range of commonly used devices. The media stability aspect assesses whether the media is free of bugs or errors during use. Meanwhile, the aesthetic aspect emphasises the media's visual appeal to make learning more interesting and fun for students.

In addition to the media expert validation instrument, this study also involves a grid of material expert validation instruments to assess the feasibility of learning content in the developed media. This instrument is prepared based on several aspects and assessment indicators, including the suitability of the material in relation to the curriculum and learning objectives. Scientific accuracy with indicators of the truth of facts and the suitability of information with the concept of ecosystems.

Visual integration with indicators of material support for students' visual literacy. Readability with communicative, clear, and easy-to-understand language use indicators—contextual relevance to the indicator of material relevance to daily life. In addition to exploring the surrounding nature, there are signs of material ability in encouraging students to observe and explore the environment. The results of this questionnaire are used to determine the validity of the material currently being developed in the media. In addition, data collection can be conducted using surveys aimed at teachers and students.

The teacher respondent questionnaire was used to gather feedback on the learning media developed. This instrument is prepared based on several aspects and assessment indicators, including the suitability of the material and the alignment of the media content with the curriculum and student needs. Aspects of the feasibility of use with indicators of ease of use of media in the classroom. The attraction aspect of indicators can capture attention and motivate students to learn. Visual literacy supports aspects that indicate the media's ability to enhance understanding through visual elements. Meanwhile, exploring the surrounding environment with media-assessed indicators encourages students to engage in environmental observation activities.

The student respondent questionnaire was used to determine the response and level of visual literacy of students regarding the developed learning media. This instrument is compiled based on several indicators of visual literacy, which include visual reasoning, visual discrimination, visual thinking, meaning construction, and knowledge of image rules. With visual

reasoning indicators, it assesses students' ability to understand the message conveyed through pictures or diagrams. The visual discrimination indicator measures students' ability to distinguish the shape and colour of visual objects. Visual thinking indicators are related to students' ability to visualize changes that occur in the ecosystem. The meaning construction indicator assesses students' ability to associate visual displays with personal experiences. Meanwhile, the image rule knowledge indicator assesses students' understanding of symbols or icons used in ecosystem images.

Data Analysis

The data analysis technique in this study employs a quantitative descriptive approach, aiming to process the results of questionnaire validation from media and material experts. The data obtained is explained in percentages to determine the feasibility level of the developed learning media. The following is a table of validation categories for media and subject matter experts, adapted from Maziyah & Zumrotun (2025).

There are categories of validation results for media and material experts, determined by the percentage of scores obtained from the assessment questionnaire. The percentage of results between 81% and 100% falls into the category of very valid, which indicates that the medium or material is already suitable for use without revision. A percentage between 61% and 80% is categorized as valid, meaning that the medium or material is worth using with slight improvement. The percentage of 41%–60% is in the category of being quite valid, indicating that the media or material still needs revision in some parts. The percentage of 21%–40% is categorised as invalid, indicating that the media or material is not yet suitable for use and requires significant improvement. Meanwhile, the percentage of 0%–20% falls into the category of being very invalid, indicating that the media or material is not suitable for use at all and needs a thorough redevelopment.

The category of response results from teachers and students is determined based on the percentage of assessment results. The assessment indicators consisted of five categories, namely very helpful with a percentage of 81%–100%, helpful with a percentage of 61%–80%, quite helpful with a percentage of 41%–60%, not helpful with a percentage of 21%–40%, and very unhelpful with a percentage of 0%–20%. This category is used to determine the extent to which the developed learning media are considered helpful to the teaching and learning process by teachers and students. The student response questionnaire was used to measure the level of visual literacy. In contrast, the teacher's response questionnaire assessed the extent to which

the media and learning materials had helped in the teaching-learning process.

RESULTS AND DISCUSSION

The development of the learning media *Ecoexplore* is tailored to the need for science learning that is not only informative but also engaging, interactive, and close to students' lives. Complex and abstract ecosystem material is often difficult to understand if it is only delivered through lectures or static images in textbooks. In the era of the Independent Curriculum and the demands of the 21st century, students are challenged to understand concepts visually and relate them to their real environment. Therefore, *Ecoexplore* was developed using Augmented Reality (AR) technology in conjunction with an approach to exploring the environment. Augmented Reality (AR) has been proven to help students understand science concepts in a more real and fun way (Zahrudin & Pratiwi, 2024). To ensure that the development is structured and on target, this media is developed through the stages of the ADDIE model, starting from analysis to evaluation. The results of these stages are presented sequentially in the following section.

Analysis Stage

In the initial stage, needs analysis is conducted through observations and interviews with teachers and students at the junior high school level. The results show that learning ecosystem materials is still dominated by lecture methods and the use of two-dimensional media, such as static images in textbooks. Students expressed difficulties in understanding the concept of interaction between ecosystem components due to the limitations of available visualizations. In addition, surveys show that most students have access to smartphone devices, but have never used Augmented Reality (AR) technology in learning.

These findings align with the study by Zahrudin & Pratiwi (2024), which states that Augmented Reality (AR) has excellent potential for improving the understanding of abstract science concepts by presenting more realistic and interactive visualizations. They identified two main approaches to using Augmented Reality (AR) for science learning: image-based and location-based, each offering advantages in enhancing students' spatial abilities and practical skills. In addition, studies (Wu, 2025) reinforce the effectiveness of image-based Augmented Reality (AR) in improving technical practice skills through interactive visual guidance.

Design Stage

Based on the results of the needs analysis, *Ecoexplore learning media was designed* by integrating Augmented Reality (AR) technology to visualize ecosystem components in three dimensions. The design of this media includes features such as

visualising the relationship between biotic and abiotic components and exploring activities in the surrounding environment, all accessible through the Assemblr Edu application.

Figure 2 is one of the visual elements designed for displaying the AR barcode, similar to Figure 1, which can be scanned using the Assemblr Edu application. By scanning the code, students will be directed to the visualization of ecosystem material in three dimensions. The following is a view of ecosystem materials.

Next, students scan the barcode using the Assemblr Edu application, which directs them to a display of ecosystem material in the form of three-dimensional visuals, as shown in **Figure 3.**

Figure 1. Barcode Display

In this view, students can see an illustration of a complete ecosystem with various biotic and abiotic components. This display is designed to allow students to learn independently and exploratively, while improving their understanding of concepts visually and contextually. The following is a visualization of the use of *Ecoexplore learning media* in ecosystem materials for student observation.

Figure 4 shows a real visualization of the use of Augmented Reality *(AR)-based* Ecoexplore learning media. In the image, it can be seen how students use smartphones to scan pre-prepared barcodes, and a three-dimensional object representing a complete ecosystem automatically appears on the student's device screen.

Figure 2. Ecosystem Material Display

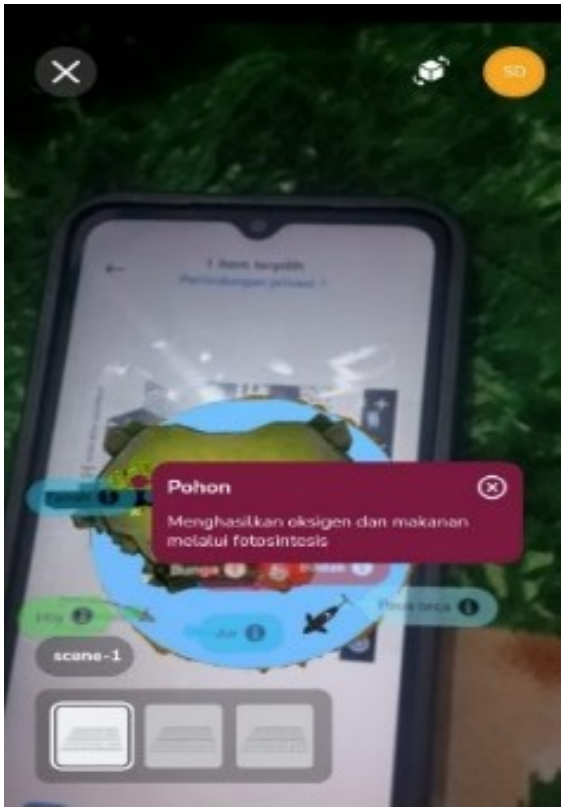

Figure 3. Usage visualization view *Ecoexplore*

This design approach is supported by findings in a systematic review by Lampropoulos & Evangelidis (2025), which states that using Augmented Reality (AR) in science learning can increase learning motivation, student engagement, and in-depth understanding of concepts, especially when combined with contextual learning and adaptive learning analytics. Other studies confirm that the perception of presence in the environment, Augmented Reality (AR), significantly encourages all aspects of learning motivation (Gandolfi & Ferdig, 2025).

Development Stage

The Ecoexplore *media development process* involves creating visual objects with Assemblr Edu and integrating them into the Augmented Reality (AR) platform. The researcher also explained the analysis used to determine the feasibility of *Ecoexplore media* through Augmented Reality (AR). After the product is completed, it will be further validated using evaluation tools developed earlier, before being implemented for students. The results of the analysis by media and material experts are then quantitatively analysed and compared with the results of the product validity test as follows.

Table 1 presents the results of the validity test of *the Ecoexplore media*, which showed very good results. Material experts gave a score of 91.67% and media experts 82.13%, both of which are in the "Very Valid" category. It shows that the content and display of the media are up to standard and are suitable for use in learning. In addition, the results of the teacher and student response test are as follows.

Table 2 presents the results of the response test conducted with teachers and students, who provided very good responses to this learning media. Teachers rated 85.71% and students 82.17%, both of which were included in the "Very Helpful" category. This media can be helpful, engaging, and really support the teaching and learning process in the classroom.

Table 1. Product Validity Test Results

Subject	Score (%)	Category
Material Expert	91.67	Highly Valid
Media members	82.13	Highly Valid

Table 2. Results of the Teacher And Student Response Test

Subject	Score (%)	Category
Teacher response	85.71	Very helpful
Student response	82.17	Very helpful

The results of the study show that the learning media developed are valid and well accepted by users, making them worthy of further testing or application in learning. These findings align with a study by Sulthon et al. (2025), which emphasises that Augmented Reality (AR) can enhance the quality of learning through an immersive and interactive environment. It also highlights the importance of collaboration between developers and educators in creating contextual and meaningful media.

Implementation Stage

Ecoexplore *media* was applied in grade VII of SMP Negeri 2 Mayong when students learned ecosystem material. The activity began with observing the environment around the school and then continued by scanning the barcode using the Assemblr Edu application. Through their phone screens, students can see ecosystems in three-dimensional form, including trees, animals, water, and land, which can be explored directly.

The students looked very enthusiastic. Students will become active in asking questions, discussing, and relating what they observe in real environments to what is shown in the media through Augmented Reality (AR). This experience makes the material feel more alive and easy to understand. It is in line with research by Pusparani & Selamat (2021), which shows that the use of Augmented Reality (AR)-based learning media can increase student engagement, clarify abstract concepts, and bridge theory and practice in science learning.

Evaluation Stage

The evaluation was carried out through a questionnaire of student and teacher responses. The results of the questionnaire showed that 89.5% of students felt that *Ecoexplore media* was very helpful in understanding ecosystem materials. In comparison, 87% of teachers assessed that this media was in accordance with the curriculum and supported students' visual literacy. In addition, there was a significant increase in students' comprehension scores after using this medium.

The results of this evaluation are consistent with the findings of a systematic review by (Toha & Panggayuh, 2024), which reported that AR-based learning media were effective in improving the understanding of concepts and the learning motivation of grade VII students. Students also emphasize that Augmented Reality (AR) can be an effective tool for improving visual literacy and understanding of complex concepts.

Today's science learning demands a more engaging, contextual, and easy-to-

understand approach, especially for complex material such as ecosystems (Lukman et al., 2022). The use of Augmented Reality (AR) technology is the right solution because it can present information visually, interactively, and effectively. Augmented Reality (AR) helps students imagine concepts that were previously only in textbooks into a lively and meaningful learning experience. As expressed by Fakhrudin & Kuswidyanarko (2020), using learning media based on Augmented Reality (AR) effectively increases students' interest and learning outcomes in science subjects in elementary school.

In this study, *the Ecoexplore learning media* developed received excellent validation results. Material experts gave a score of 91.67% and media experts 82.13%, both in the "Very Valid" category. This media is considered appropriate in terms of content, appearance, and functionality. In addition, teachers and students involved in the trial also gave positive responses, with teachers scoring 85.71% and students 82.17%. This response shows that *Ecoexplore* is not only interesting but also helpful in the teaching and learning process.

Based on this data, *Ecoexplore* has succeeded in bridging the gap between theory and practice. Students do not view the material as a collection of concepts; instead, they can directly relate it to the surrounding environment through a nature exploration approach. It strengthens their ability to understand and connect information visually, which is at the core of visual literacy. In addition, teachers are also helped because this media not only supports the curriculum, but also encourages students to explore actively.

This finding is reinforced by recent research conducted by Ziden et al. (2022), which found that the use of Augmented Reality (AR) in NutricARd significantly improves student achievement and motivation in science learning. The study shows that Augmented Reality (AR) not only improves understanding of concepts but also encourages students' active involvement in the learning process. In addition, research by Eldokhny & Drwish (2021) emphasised that AR is effective in supporting academic achievement and skill mastery in distance learning during the COVID-19 pandemic. These findings show that Augmented Reality (AR) can be a powerful tool in a variety of learning contexts, including online and offline learning.

Thus, *Ecoexplore* is present not only as a visual aid, but as a learning companion that is close to the real world of students. This media helps students understand the ecosystem not only through the words in the book but also through experiences they can see, explore, and feel for themselves. It is a small but meaningful step toward more

human science learning that feels close, grounded, and fun. When students can feel the connection between the lesson and the surrounding environment, the learning process becomes more lively. Moreover, from those small experiences grow care, curiosity, and awareness to take care of the earth that students live in every day.

The results of the study show that *Ecoexplore* learning media have a high level of effectiveness and validity, but several limitations need to be considered. First, the trials carried out are still limited to a small scale with a relatively small number of teachers and student respondents. This condition prevents the results of the study from being generalized thoroughly to the broader population. Second, the focus of this research is more on media validation and user response, so it has not explored in depth how the use of *Ecoexplore* can affect the improvement of student learning outcomes, both in terms of cognitive, affective, and psychomotor aspects. Third, in terms of implementation, there are still challenges related to the availability of technology infrastructure in schools, such as devices supporting Augmented Reality (AR) and uneven internet connection stability. These factors are obstacles to the optimal implementation of media in various learning environments.

Based on the results and limitations found, further research is recommended with a wider scope to provide a more representative picture. The *Ecoexplore trial* should involve more schools with diverse backgrounds and conditions, so that the effectiveness of these media can be tested in a variety of learning contexts. In addition, the development of advanced versions of *Ecoexplore* can be directed towards a more interactive and adaptive form. It could involve adding an automatic evaluation feature, Augmented Reality (AR)-based quizzes, or educational games that allow students to learn while interacting directly with the learning content.

The subsequent research can examine the application of *Ecoexplore* in the project-based learning (PBL) model or collaborative learning. This approach is expected to provide a better picture of how Augmented Reality (AR) technology fosters critical thinking, problem-solving, and cooperation among students in more authentic learning situations.

Future research is expected not only to assess short-term effectiveness but also to explore the long-term impact of Augmented Reality (AR) use on students' learning motivation and knowledge retention. In-depth studies on teacher readiness, school support, and education policies for integrating Augmented Reality (AR) technology are also important to ensure the sustainable use of media such as *Ecoexplore*. With these steps, the results of advanced

research are expected to enrich innovation in science learning and provide honest guidance for educators in creating a learning experience that is contextual, engaging, and aligned with the demands of 21st-century education.

CONCLUSION

Ecoexplore learning media developed with Augmented Reality (AR) technology and an environmental exploration approach is efficacious in improving students' visual literacy competencies. This medium not only presents the concept of ecosystems theoretically but also relates them to the real environment, providing a more lively, contextual, and meaningful learning experience. The validation results from material and media experts show that *Ecoexplore* is very suitable for use in both content and display. In addition, the positive response from teachers and students shows that this media can make science learning more interesting, interactive, and relevant to technological developments and current needs. Thus, *Ecoexplore* has proven to be effective as an innovative learning medium that can enhance students' visual literacy and support science learning that is applicable and oriented to real experience.

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