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Developing Augmented Reality Media On Ecosystems In Science Learning For Grade Vii Students

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Abstract. The development of technology-based learning media has become an essential strategy for improving the quality of science education at the junior secondary school level, particularly in ecosystem topics that require students to understand the interrelationships among ecosystem components comprehensively. In classroom practice, students often encounter difficulties in understanding these concepts because the material is abstract in nature, while instruction is still predominantly conducted through lecture-based methods and textbook-centered learning. This study aimed to develop a Web Augmented Reality (AR)-based learning medium for ecosystem topics that is valid, practical, and effective for use in seventh-grade science learning. The research employed a Research and Development (R&D) approach using the ADDIE model, which consists of the Analysis, Design, Development, Implementation, and Evaluation phases. Data were collected through observations, interviews, expert validation, student response questionnaires, and pretest-posttest assessments. The results indicated that the developed learning media were categorized as valid based on evaluations conducted by both material and media experts. Student responses to the media reached a percentage of 78.06%, indicating that the media were considered practical and appropriate for classroom use. The effectiveness of the media was demonstrated by an increase in students' mean scores from 2.40 on the pretest to 4.25 on the posttest, with an N-gain score of 0.71 (71%), which falls into the high category. Furthermore, the Paired Sample t-Test yielded a significance value of 0.000 ($p < 0.05$), indicating a statistically significant difference between students' learning outcomes before and after the implementation of the media. Therefore, the Web Augmented Reality-based learning media on ecosystem topics can be considered valid, practical, and effective in supporting science learning for seventh-grade students.

Keywords: Augmented Reality (AR); Learning Media; Ecosystem; Science Learning; Research and Development (R&D).

I. INTRODUCTION

Background of the Study

Science education at the junior high school level plays a crucial role in fostering students' scientific understanding of natural phenomena through observation, inquiry, and problem-solving activities. Under the Merdeka Curriculum, seventh-grade science learning emphasizes the acquisition of ecological concepts, including biotic and abiotic components, interactions among living organisms, food chains, and ecosystem balance [1]. These concepts require students to develop conceptual thinking skills, as they are expected not only to memorize factual information but also to understand the interrelationships among ecosystem components within a comprehensive system [2]. Despite its importance, the teaching of ecosystem concepts continues to face several challenges. Learning activities are frequently dominated by textbooks and teacher-centered verbal explanations, resulting in insufficient visualization of abstract concepts [3]. Consequently, students often encounter difficulties in understanding the relationships among ecosystem components and the ecological processes occurring within them [4]. Given that junior high school students are transitioning toward the formal operational stage of cognitive development, they require learning experiences that are contextual, visual, and interactive to support meaningful learning. Furthermore, the limited availability of instructional media capable of presenting ecosystem phenomena in a concrete and engaging manner contributes to low levels of student participation and engagement during classroom instruction [5]. Advances in digital technology provide opportunities to create innovative learning experiences that

meet the demands of twenty-first-century education. One promising technology for science education is Augmented Reality (AR), which enables the integration of three-dimensional virtual objects into real-world environments in real time. Through this technology, students can observe and interact with representations of objects and phenomena that are difficult to access directly. Previous studies have demonstrated that AR can enhance conceptual understanding through concrete visualization, increase learning interactivity, and promote active student engagement throughout the learning process [6]. Therefore, the development of AR-based learning media for ecosystem topics is necessary to support the characteristics of junior high school students and to meet the learning objectives outlined in the Merdeka Curriculum. The research problem addressed in this study is how to develop a Web-based Augmented Reality learning medium for ecosystem topics that is valid, practical, and effective for use in science learning among seventh-grade junior high school students.

Augmented Reality (AR) has been widely utilized in science education due to its potential to enhance learning motivation, student engagement, and conceptual understanding through interactive and contextual visualization [7]. AR-based learning media have proven effective in visualizing objects and phenomena that are difficult to observe directly, thereby supporting students in understanding abstract scientific concepts [8]. However, most existing studies and development projects have focused on AR applications that require installation on specific devices, while the development of Web-based Augmented Reality (Web AR) learning media that can be accessed directly through web browsers remains relatively limited [9]. The novelty of this study lies in the development of Web-based Augmented Reality learning media for ecosystem topics designed specifically for seventh-grade junior high school students in accordance with the learning outcomes of the Merdeka Curriculum. Unlike conventional AR applications, the developed media not only provide three-dimensional object visualizations but also integrate instructional content, learning activities, and exploratory tasks within a single platform that can be accessed without the need for additional software installation. This approach is expected to offer a more flexible, interactive, and accessible learning experience while addressing the educational needs of students in the digital era.

A research gap is a question or issue that has not been addressed by any of your field's existing studies or research. Occasionally, a research gap exists when a concept or new idea has never been studied. There may be a research gap if all existing research is obsolete and requires new/updated research (studies on Internet use in 2001, for example). Or perhaps a particular population has not been sufficiently studied (perhaps there are plenty of studies on teenagers and video games, but not enough studies on toddlers and video games, for example). These are merely a few examples, but any research gap you identify is an area where additional studies and research must be conducted.

Problem of the Study

The problem addressed in this study is the limited availability of accessible, interactive, and curriculum-aligned learning media that can visualize ecosystem concepts for Grade VII students. Existing learning activities may not provide sufficient three-dimensional visualization or opportunities for students to explore relationships among ecosystem components. In addition, many AR learning media require application installation, which can create technical barriers to classroom use. Thus, a learning medium that combines interactive three-dimensional visualization, instructional content, and browser-based accessibility is needed.

Research's State of the Art

Research on AR in education has increasingly demonstrated its potential to improve learning motivation, engagement, and conceptual understanding through interactive visualization [6]–[8]. In science education, AR is particularly useful for representing objects and processes that are difficult to observe directly. Nevertheless, much of the existing development has focused on application-based R, while Web-based AR remains comparatively less explored as an accessible learning platform. In addition, the integration of three-dimensional ecosystem visualization with instructional content and learning activities in a single browser-based medium remains an area requiring further development.

Gap Study and Objective

Based on the literature, the research gap lies in the limited development of Web AR media specifically designed for Grade VII ecosystem learning and aligned with the learning needs of the Merdeka Curriculum. This study therefore aimed to develop a Web AR-based learning medium for ecosystem topics and to determine its validity, practicality, and effectiveness in supporting students' conceptual understanding.

The novelty of this study lies in integrating ecosystem learning content, interactive three-dimensional

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visualization, instructional activities, and browser-based accessibility into a single Web AR learning medium. Unlike application-based AR media, the developed product can be accessed through a web browser without requiring additional software installation.

II. METHOD

Type and Design

This study was conducted with seventh-grade students at SMP Islam Mandiri Bojonggede as the primary target users of the learning media. The research falls within the field of education and employed a Research and Development (R&D) approach by adopting the ADDIE development model, which consists of five stages: Analyze, Design, Development, Implementation, and Evaluation. The ADDIE model was selected because its stages are systematically and logically structured, making it practical and efficient for the development of educational media.

The R&D method was utilized to develop an Augmented Reality-based learning medium and to evaluate its feasibility for classroom implementation. Prior to the development process, a comprehensive needs analysis was conducted to ensure that the resulting media aligned with the characteristics, learning conditions, and educational needs of the students.

Figure 1. Stages of Augmented Reality media development

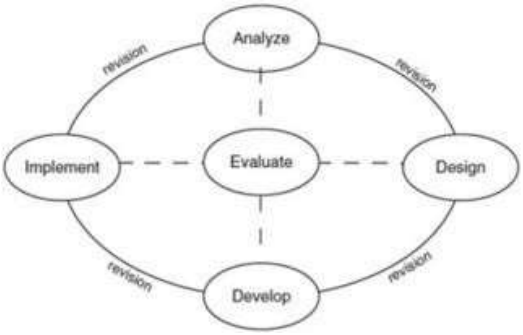

Figure 2. Stages of the ADDIE model

1. Analysis
   The analysis stage was conducted to identify the needs and feasibility of developing an Augmented Reality (AR)-based learning medium for ecosystem topics. This stage began with classroom observations and interviews at the school to examine the existing science learning process, including the instructional media used, teaching

models implemented by teachers, and students' difficulties in understanding ecosystem concepts. The analysis also involved a review of the curriculum, learning materials, and the characteristics of seventh-grade junior high school students. The findings from this stage served as the foundation for determining the specifications of the Augmented Reality-based learning media to ensure its alignment with students' needs and learning objectives.

2. Design
   The design stage involved planning the Augmented Reality-based learning media, including the formulation of learning objectives, selection of ecosystem content, and development of a storyboard. This stage also encompassed the design of the user interface, the selection of three-dimensional visual objects, and the organization of user interaction flows within the Web-based Augmented Reality (Web AR) environment. The media was designed to be visually appealing, user-friendly, and capable of facilitating students' understanding of ecosystem components and their interactions through direct engagement with virtual objects.
3. Development
   The development stage focused on transforming the designed concept into a functional Augmented Reality-based learning product. Activities included creating three-dimensional ecosystem objects, integrating Augmented Reality technology, and developing instructional content in accordance with the curriculum. The initial product was subsequently subjected to expert validation to assess its quality, appropriateness, and feasibility for educational use.
4. Implementation
   The Augmented Reality (AR) learning media that had passed the expert validation process was then implemented in classroom learning activities as an instructional medium. This stage was conducted on a limited scale involving a small group of students as trial participants. The learning process began with the administration of a pre-test to measure students' prior knowledge of ecosystem concepts. Students then participated in learning activities using the developed Augmented Reality media. Upon completion of the learning session, a post-test was administered to evaluate changes in students' understanding after using the media. In addition, students were asked to complete a response questionnaire to provide feedback regarding the usability and effectiveness of the learning media.
5. Evaluation
   The final stage of the ADDIE model was evaluation. This stage aimed to assess the quality of the developed Augmented Reality (AR) learning media in terms of its validity, practicality, and effectiveness in supporting learning activities. The evaluation results were used to identify the strengths and weaknesses of the product. Any technical issues or learning difficulties encountered by students were considered for further revisions and improvements. The evaluation findings also served as supporting data for addressing the research questions and enhancing the quality of the learning media for future implementation.

Data and Data Sources

This research resulted in a web-based Augmented Reality (AR) learning media for the topic of ecosystems for seventh-grade students at SMP Islam Mandiri Bojonggede. The media was developed using the ADDIE model, which includes analysis, design, development, implementation, and evaluation. The resulting product can be accessed via smartphone or laptop without requiring additional application installation, making it easy for users to access the learning media anytime and anywhere.

Data Collection Technique

Data collection techniques in this study included observation, interviews, questionnaires, and tests. Observations and interviews were conducted during the analysis phase to identify learning needs and problems faced by students in the ecosystems material. Questionnaires were used to obtain validation data from material experts and media experts, as well as student responses to the developed media. Furthermore, pretests and posttests were administered during the implementation phase to measure improvements in students' conceptual understanding after using web-based Augmented Reality learning media.

Data Analysis

Data were analyzed using quantitative descriptive analysis and inferential statistics. Data from material expert validation, media expert validation, and student responses were converted into percentage values and then interpreted based on predetermined criteria. Pretest and posttest data were analyzed using N-gain scores to

determine the increase in students' conceptual understanding. Paired Sample t-Test was used to identify significant differences between pretest and posttest results after using Web-based Augmented Reality learning media.

III. RESULTS

This research produces a Web-based Augmented Reality (AR) learning media on ecosystem material for seventh-grade students of SMP Islam Mandiri Bojonggede. The developed media can be accessed via smartphone or laptop through a browser without requiring the installation of additional applications. The material presented includes biotic and abiotic components, interactions between living things, food chains, food webs, and energy flow in ecosystems visualized in the form of interactive three-dimensional objects. The validation results by material experts and media experts indicate that the developed media is in the category of being suitable for use in learning. Several improvements were made to the appearance, navigation, and presentation of the material according to the validator's input so that the media becomes easier to use and understand for students.

Table 1. Calculation of N-gain Values

Average Value		N-Gain	N-Gain (%)	Category
Pretest	Posttest			
2,40	4,25	0,71	71%	Effective (High)

The effectiveness of the media was analyzed through the results of the students' pretest and posttest. The average pretest score of 2.40 increased to 4.25 in the posttest. The N-Gain calculation result of 0.71 or 71% is included in the high category. These results indicate that the use of Web-based Augmented Reality learning media is able to improve students' conceptual understanding of ecosystem material. This finding is supported by the results of the Paired Sample t-Test which showed significance value of 0.000 ($p < 0.05$), indicating a significant difference between students' abilities before and after using the learning media. The improvement in learning outcomes shows that the three-dimensional visualization presented through Augmented Reality technology is able to help students understand abstract ecosystem concepts. Through this media, students can observe the relationship between biotic and abiotic components, food chains, food webs, and energy flows more concretely, thus facilitating the process of forming conceptual understanding. Student responses to the developed media obtained a percentage of 78.06% with a decent category. These results indicate that the media can be well received by students and supports the learning process. Attractive visual appearance, ease of use, and direct interaction with three-dimensional objects are factors that support students' positive responses to learning media.

Discussions

Novelty and contribution

The results of the study indicate that the developed Augmented Reality (AR) web-based learning media is effective in improving students' conceptual understanding of ecosystems. This effectiveness is demonstrated by an increase in students' average score from 2.40 in the pretest to 4.25 in the posttest, an N-Gain value of 0.71, which is considered high, and a Paired Sample t-Test showing a significant difference between the pretest and posttest results ($p < 0.05$). These findings indicate that three-dimensional visualizations presented through AR technology can help students understand abstract ecosystem concepts, such as the relationship between biotic and abiotic components, food chains, food webs, and energy flow. These findings align with research by Uno (2024) which states that Augmented Reality-based learning media can improve understanding of science concepts through more engaging and interactive presentations. These results also support the findings of Afnan and Puspitawati (2024) who explain that Augmented Reality technology can facilitate the process of knowledge construction through exploration and interaction with virtual objects. The primary contribution of this research lies in the development of web-based Augmented Reality learning media that can be accessed directly through a browser without requiring additional application installation. This feature provides easy access for teachers and students, allowing the media to be used on various devices, including smartphones and laptops. Thus, this research not only contributes to the development of AR-based learning media but also offers a more practical and easily implemented digital learning alternative in the

school environment.

Limitation and future study

This study has several limitations. The media implementation was conducted in only one school with a limited number of participants, so the results cannot be broadly generalized. Furthermore, the media testing focused only on ecosystems material and measured short-term improvements in conceptual understanding. This study also did not examine the media's influence on other aspects, such as learning motivation, critical thinking skills, or student retention.

Future research is recommended to involve a larger number of participants from various schools with different characteristics. The media development can also be applied to other science materials to determine the consistency of Web Augmented Reality's effectiveness in various learning contexts. Studies on the media's influence on learning motivation, higher-order thinking skills, and long-term learning outcomes are also needed to gain a more comprehensive understanding.

Implication and suggestions

The research results show that Web Augmented Reality has the potential to be an innovative and effective learning medium for science. The medium's ability to present interactive three-dimensional visualizations helps students understand concepts that are difficult to observe directly, making learning more meaningful. Easy access via a browser without installing additional applications also supports the medium's implementation in classroom learning activities and independent learning. Teachers can utilize Web Augmented Reality-based media as an alternative to increase student engagement and facilitate conceptual understanding of abstract material. Schools need to support the use of digital learning technology by providing adequate facilities for optimal implementation. Learning media developers are also advised to continuously refine Web Augmented Reality features and content to make them more interactive, user-friendly, and tailored to student needs.

IV. CONCLUSION

This research contributes to the development of digital learning media by presenting innovation in the form of integrating ecosystem material and three-dimensional object visualization in a Web Augmented Reality platform that is more accessible than application-based AR. The presence of this media expands the use of AR technology in science learning while offering a flexible learning alternative that is appropriate to the needs of students in the digital era. However, this research is still limited to implementation in one school and on ecosystem material. Future research can expand the application of the media to other science materials, involve more diverse subjects, and examine the effect of the use of Web Augmented Reality on learning motivation, critical thinking skills, and long-term learning retention of students.

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