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Enhancing Elementary Students' Ecosystem Understanding Through Environment-Based Interactive Learning Media Using Genially: An SDG 4 Perspective

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Abstract: Science learning in elementary schools still faces challenges because ecosystem concepts are abstract and difficult for students at the concrete operational stage to understand. This study aimed to develop environment-based interactive learning media using the Genially platform and examine its effectiveness in improving students' understanding of ecosystem concepts. This research employed a Research and Development (R&D) method using the ADDIE model, including analysis, design, development, implementation, and evaluation stages. The development phase resulted in interactive media integrating visual illustrations, animations, ecosystem simulations, and gamified quizzes. The product was validated by subject matter experts and media experts, obtaining scores of 92% and 93%, respectively, categorized as very suitable. The trial was conducted using a purposive sampling technique with 31 fifth-grade students at Pasar Bunder Elementary School, Cilegon City. Data were analyzed using descriptive statistics and the N-Gain test. The results showed that the average score increased from 50 (pretest) to 86 (posttest), with an N-Gain value of 0.72 (high category). In conclusion, the developed Genially-based learning media is effective in improving students' understanding of ecosystem concepts through interactive and visual representations of environmental contexts.

Keywords: Conceptual understanding; Ecosystem; Elementary students; Environment-based learning; Genially

Introduction

The challenge of achieving quality education, as outlined in the Sustainable Development Goals (SDG 4), highlights the importance of inclusive, equitable, and effective learning supported by innovation and technology integration. In the context of 21st-century education, the use of digital technology is no longer optional but has become essential for improving the quality and accessibility of learning (Okulich-kazarin, 2025; Yang et al., 2025; Anedin, 2024). This is further supported by other studies emphasizing the critical role of technology integration in enhancing educational quality (Syafarudin & Ardiansyah, 2025; Oktaviani & Nugraheni, 2024). However, science learning in elementary schools still faces significant challenges, particularly in teaching abstract concepts such as ecosystems. Ecosystem materials involve complex interactions between biotic and abiotic components that are often difficult for students to visualize and understand concretely. Several studies indicate that students' conceptual understanding of ecosystem topics remains low (Bambang et al., 2025; Sulysiah et al., 2024; Yuliawati et al., 2024). This condition is caused by the abstract nature of the material and the limitations of conventional teaching approaches (Aen & Kuswendi, 2020; Wahidin et al., 2025; Wardani, 2022).

To address these challenges, environment-based learning has been widely recognized as an effective strategy for making science learning more contextual and

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meaningful (Akinsemolu & Onyeaka, 2025; Arntzen et al., 2025; Erfan et al., 2025). This approach connects learning materials with students' real-life environments, enabling them to directly observe and relate scientific concepts to everyday experiences (Karim & Nasrianty, 2023; Kurniyah et al., 2021; Wijanarko & Sujarwo, 2024). Furthermore, the surrounding environment provides authentic and relevant learning resources for understanding ecosystem concepts (Firdaus et al., 2021; Ningsih et al., 2023). However, in practice, the implementation of environment-based learning often encounters several constraints, such as limited time, unpredictable weather conditions, safety concerns, and limited access to observation objects, resulting in suboptimal utilization.

As a solution to these limitations, the integration of interactive digital learning media offers a promising alternative to support environment-based learning. Interactive media can simulate real-world phenomena and present dynamic visualizations (Martins et al., 2025; She et al., 2024). In addition, digital media provide flexible learning experiences and accommodate various student learning styles (Fadilah et al., 2023). One platform that can be utilized is Genially, which enables the development of interactive multimedia learning by integrating elements such as text, images, animations, videos, and quizzes into a unified display. Previous studies have shown that Genially-based media can enhance student engagement and participation in learning (Yuniarsih et al., 2025; Claudia et al., 2025; Agustin et al., 2025). Moreover, the use of Genially has been proven to improve students' learning motivation and literacy skills at the elementary level (Kholisna & Sukasih, 2025; Sitinjak et al., 2025).

The effectiveness of interactive multimedia learning media can be explained through Mayer's Cognitive Theory of Multimedia Learning (CTML), which states that students learn more effectively when information is presented through both visual and auditory channels. In this study, the design of Genially-based media applies the coherence principle by eliminating irrelevant information and the segmentation principle by organizing content into structured sections (Çeken et al., 2022). In addition, the dual-channel principle is implemented through the use of animated ecosystem visuals combined with audio narration to strengthen students' cognitive processing (Rahimi & Shute, 2021). Through this approach, students are expected to process information more effectively through the stages of selecting, organizing, and integrating knowledge.

The characteristics of elementary school students, who are in the concrete operational stage, require learning media that are visual, contextual, and interactive. Ecosystem materials, which are closely related to real-world phenomena such as plants, animals, soil, and water, are highly suitable to be presented through environment-based media. The use of rich visualizations, animations of ecosystem interactions, and contextual simulations can help concretize abstract concepts and improve students' understanding (Cho et al., 2018; Sung et al., 2016). In addition, visually rich media with colors and images have been proven to attract students' attention and support more effective science learning (Wardani, 2022).

Although numerous studies on interactive learning media have been conducted, several research gaps remain. Previous studies have generally focused on the use of digital media or Genially independently, without specifically integrating an environment-based approach into ecosystem materials at the elementary school level (Saktilia & Wulandari, 2024; Istmadelia & Tyas, 2024). Furthermore, studies linking the development of learning media with the SDG 4 perspective are still limited (Rukoyah & Bektiningsih, 2024).

Therefore, the novelty of this study lies in the development of environment-based interactive learning media using Genially specifically designed for ecosystem materials in elementary schools and aligned with the SDG 4 perspective. This study integrates digital interactivity with real-world environmental contexts while systematically applying multimedia learning principles. Thus, this research is important as it has the potential to overcome the limitations of both conventional and environment-based learning, provide innovative solutions for teachers, and improve students' conceptual understanding of ecosystems through interactive, meaningful, and contextual learning experiences.

Method

This study employed a Research and Development (R&D) approach aimed at developing an interactive, environment-based learning media using Genially and examining its effectiveness in improving elementary school students' understanding of ecosystem concepts. The R&D method was selected because it enables the systematic development of educational products that are valid, practical, and aligned with real learning needs (Nengsih et al., 2025). This approach is also widely used in educational product development to ensure the quality and applicability of learning media (Rehdaya & Tyas, 2024). Furthermore, R&D supports iterative revisions based on evaluation results to produce effective learning tools (Maharani & Ramadan, 2023).

The development process followed the ADDIE model, which consists of five stages: analysis, design, development, implementation, and evaluation. This model was chosen due to its systematic structure and flexibility in developing instructional media (Rehdaya & Tyas, 2024). In addition, the ADDIE model is widely

applied in technology-based learning development due to its clear procedural steps (Maharani & Ramadan, 2023). Its iterative nature also allows continuous improvement during the development process (Istmadelia & Tyas, 2024). The overall research procedure follows a systematic flow.

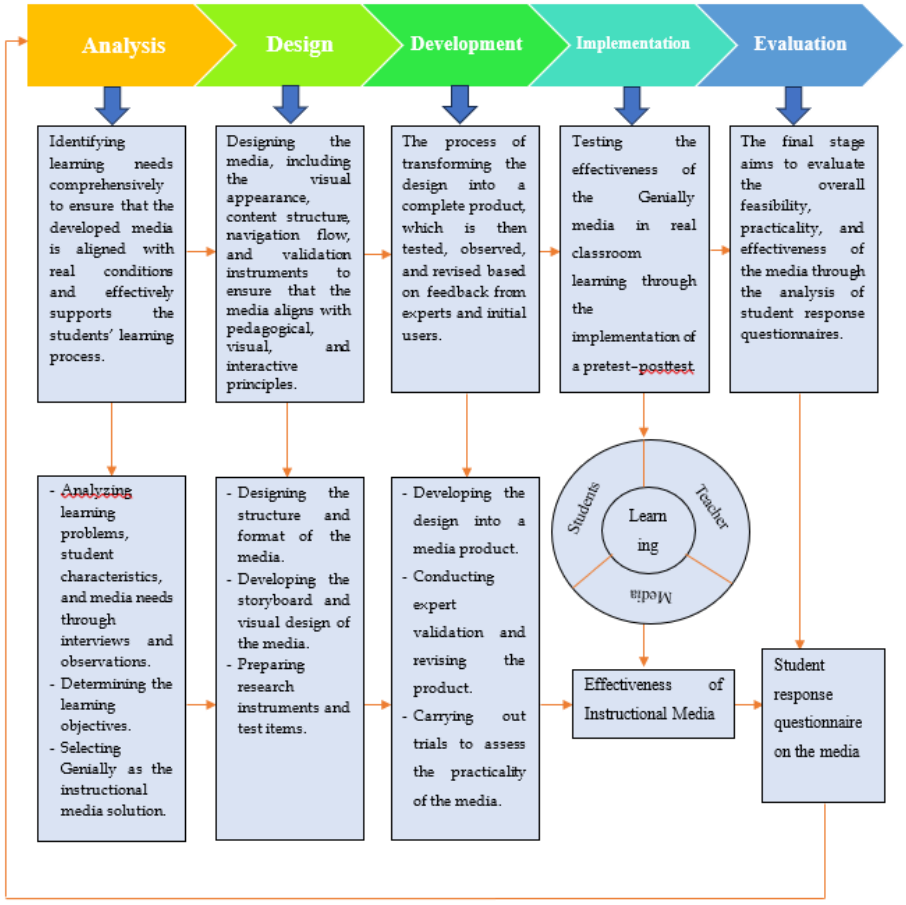

Figure 1. Product development stages

This study used an R&D approach with quantitative descriptive analysis, supported by qualitative data to strengthen the findings. Quantitative data were obtained from pretest and posttest scores to measure students' conceptual understanding, while qualitative data from observations and questionnaires were used to support and interpret the quantitative results. Thus, qualitative findings functioned as explanatory data to strengthen the effectiveness results obtained quantitatively.

The research subjects were determined using purposive sampling, consisting of 31 fifth-grade students of SDN Pasar Bunder, Cilegon City. The subjects were selected based on their relevance to the research objectives, particularly students who were studying ecosystem material and demonstrated relatively low conceptual understanding based on previous learning evaluations.

The research procedure began with the analysis stage, which involved identifying learning needs, student characteristics, and problems in science learning through classroom observations, teacher interviews, and curriculum analysis. The findings indicated that learning was still dominated by conventional methods, leading to students' difficulties in understanding abstract ecosystem concepts. The next stage was design, in which the learning media was planned in terms of content structure, navigation, interface design, and interactive features. At this stage, research instruments were also developed, including pretest-posttest items, student response questionnaires, and observation sheets.

The development stage involved producing the Genially-based interactive learning media, which included ecosystem materials, environmental visualizations, animations, and interactive quizzes. At this stage, expert validation was conducted before the product was implemented. The validation involved at least two experts, namely a subject matter expert and a media expert. The validation process used a Likert scale questionnaire (1–5) covering aspects such as content accuracy, language clarity, visual design, interactivity, and usability. The validation results were analyzed to determine the feasibility of the product and used as the basis for revision.

After expert validation, a limited trial (small group trial) was conducted involving 5 students to evaluate the practicality and usability of the media. This stage aimed to identify issues related to instructions, navigation, and student interaction. Feedback obtained from students during this trial was used to revise and improve the product before it was tested in a larger group.

The implementation stage (field trial) was conducted in a classroom setting involving 31 students. Before the learning process, students were given a pretest to measure their initial understanding of ecosystem concepts. The learning process was then carried out using the developed environment-based Genially media, allowing students to actively interact with the content. After the learning activities were completed, students were given a posttest to measure the improvement in conceptual understanding.

The evaluation stage consisted of formative and summative evaluation. Formative evaluation was conducted during the development stage through expert validation and limited trials, ensuring that revisions were based on expert judgment and student feedback. Meanwhile, summative evaluation was conducted after the implementation stage to assess the effectiveness of the learning media. The summative evaluation used data from posttest results, N-gain analysis, student response questionnaires, and observation of learning activities.

Data collection techniques included tests, questionnaires, and observations. Tests were used to obtain quantitative data in the form of pretest and posttest scores. Questionnaires were used to collect students' responses regarding the attractiveness, ease of use, and effectiveness of the media, while observations were used to assess student engagement during the learning process. Before use, the test instruments were tested for validity and reliability to ensure that they adequately measured students' understanding of ecosystem concepts (Rukoyah & Bektiningsih, 2024). Reliability testing is essential to ensure the consistency of measurement results in educational research (Pane et al., 2024).

Quantitative data analysis was conducted using the N-gain formula to determine the effectiveness of the learning media in improving students' understanding:

$$N_{Gain} \frac{\text{Postest Score} - \text{Pretest}}{\text{Maximum Score} - \text{Pretest}} \quad (1)$$

The results of the N-gain calculation were then categorized into low, medium, or high improvement criteria according to the learning outcome improvement criteria. Qualitative data analysis was conducted by describing the observation results and student responses narratively to strengthen the quantitative findings. The learning outcome improvement categories were determined based on the following criteria.

Table 1. Criteria for increasing cognitive values

Limitation	Category
$g \geq 0.70$	High
$0.30 \leq g < 0.70$	Currently
$g < 0.30$	Low

Qualitative data from observations and questionnaires were analyzed descriptively to support and strengthen the quantitative findings. Through these procedures, the research method is expected to provide a clear, systematic, and validated description of both the development process and the effectiveness of the environment-based Genially learning media in improving elementary school students' understanding of ecosystem concepts.

Result and Discussion

The results of this study are presented to address the main objectives of the research, namely to develop Genially-based interactive learning media integrated with a digital-virtual environmental context and to examine its validity, practicality, and effectiveness in improving fifth-grade elementary students' understanding of ecosystem concepts. The presentation of the findings is organized systematically based on the development stages that have been carried out, thereby providing a comprehensive overview of the quality of the developed product and its impact on the learning process.

More specifically, the findings encompass three main aspects: validation results from subject matter experts and media experts to determine the feasibility of the product; practicality test results based on teachers' and students' responses to measure the ease of use of the media; and effectiveness test results through the analysis of students' learning outcome improvement using a pretest–posttest design. In addition, the results also describe the characteristics of the developed media, including its interactive features, concept visualizations, and the integration of environmental context in a digital-virtual form designed to support more contextual and meaningful learning. Thus, the presentation of the results not only focuses on quantitative data in the form of scores and percentages, but also provides a clear description of the developed product and its contribution to enhancing the quality of science learning, particularly in ecosystem topics at the elementary school level.

Product Description

The product developed in this study is a Genially-based interactive learning media on ecosystem material. The media is designed by integrating several key components, including visualizations of biotic and

abiotic components, animations of energy flow and food chains, interactive simulations, and quizzes with automatic feedback. The environmental aspect is incorporated through visual representations and ecosystem simulations in the form of digital-virtual environment integration, serving as an alternative to the limitations of direct field observation. The media is designed with an engaging visual appearance, simple navigation, and interactive activities that promote active student engagement.

Figure 2. The main interface of the Genially media

Figure 3. Substance material (content)

Figure 4. Food chain simulation

Figure 5. Practice questions and feedback

Figure 6. Small-scale product trial

Figure 7. Large-scale product trial

Expert Validation Results

The validation of the learning media was conducted by two validators, namely a subject matter expert and a media expert, using a Likert scale–based assessment instrument covering several important aspects. The evaluation by the subject matter expert included content alignment with the curriculum, conceptual accuracy, depth of material, and the relevance of the content to environmental contexts. Meanwhile, the evaluation by the media expert focused on visual appearance, interface design, navigation, interactivity, and clarity of information presentation within the media.

Table 2. Expert validation results

Assessment aspect	Percentage (%)	Criterion
Subject matter expert	92.00	Highly valid
Media expert	94.00	Highly valid

The validation results indicate that the media falls into the "highly valid" category and is suitable for implementation in the field trial stage. This finding is supported by previous studies showing that interactive learning media validated by experts tend to have more assured quality before being used in the learning process (Rukoyah & Bektiningsih, 2024).

Practicality Test Results

The practicality test was conducted to determine the level of ease of use and user acceptance of the media by teachers and students. This test was carried out through response questionnaires administered after the media was implemented during the small-scale trial phase. The questionnaire instrument was designed using a Likert scale, covering several aspects, including ease of use, clarity of display, attractiveness of the media, and its usefulness in supporting the learning process.

Table 3. Practicality test results

Respondent	Percentage (%)	Criterion
Teacher	95.00	Highly practical
Students	90.00	Highly practical

These findings indicate that the media is not only theoretically feasible but also practical for use in real classroom learning contexts. This result is consistent with previous studies stating that Genially-based interactive media can enhance student engagement and generate positive responses in the learning process (Yuniarsih et al., 2025). Therefore, the high level of practicality serves as an important indicator that the developed learning media can be effectively implemented in elementary school science learning.

Prerequisite Test (Normality)

The normality test was conducted to determine whether the pretest and posttest data were normally distributed as a requirement for further statistical analysis. In this study, the normality test was performed using the Shapiro–Wilk test because the sample size was fewer than 50 students.

Table 4. Normality test results

Data	Sig. (p-value)	Description
Pretest	0.08	Normal
Posttest	0.09	Normal

Based on the results of the normality test, the significance (Sig.) value for the pretest data was 0.08 and for the posttest data was 0.09. Both values are greater than 0.05 (Sig. > 0.05), indicating that the data are normally distributed. Since the normality assumption is fulfilled, further analysis using the N-Gain test can be conducted appropriately and is statistically justifiable. In addition, the normal distribution of the data indicates that the improvement in students' learning outcomes occurred relatively evenly, suggesting that the research findings have a good level of reliability in representing the effectiveness of the developed learning media.

Effectiveness Test Results

The effectiveness of the Genially-based interactive learning media was tested using a one-group pretest–posttest design involving 31 fifth-grade elementary school students. This test aimed to determine the extent to which the use of the media could improve students' understanding of ecosystem concepts after participating in the learning process. Before the learning began, students were given a pretest to measure their initial ability, and after learning using the media, a posttest was administered to assess the improvement in conceptual understanding.

Table 5. Pretest, posttest, and N-Gain results

Research Aspects	Average value	Category
Pretest	50	
Posttest	86	High
N-Gain	0.72	

Based on the results of the descriptive analysis, the average pretest score was 50, indicating that students' initial understanding of ecosystem material was still in the moderate category. After learning using the Genially-based media, the average posttest score increased to 86, showing a significant improvement in conceptual understanding. Furthermore, the N-Gain calculation resulted in a value of 0.72, which falls into the high category.

These findings indicate that the developed learning media has good effectiveness in improving students' understanding of ecosystem concepts. The significant increase between pretest and posttest scores suggests that the presentation of material through visualizations, animations, and interactive simulations helps students transform previously abstract concepts into more concrete and understandable forms. Furthermore, the results demonstrate that the developed media not only functions as an instructional aid but also as a tool that facilitates students' knowledge construction more optimally.

Student Score Distribution

The distribution of student scores indicates that most students experienced an improvement from the moderate category to the high category after participating in learning using the Genially-based media. During the pretest, the majority of students were in the moderate category, and some were still in the low category, indicating that their initial understanding of ecosystem concepts was not yet optimal. However, after the implementation of interactive media-based learning, there was a significant shift in the score distribution, with most students reaching the high category in the posttest.

Table 6. Distribution of pretest and posttest student scores

Category	Score range	Pretest (number of students)	Posttest (number of students)
High	≥ 70	6	24
Moderate	40 – 69	18	7
Low	< 40	7	0
Total		31	31

This shift in distribution indicates that the improvement in learning outcomes did not occur only among a small number of students but was relatively evenly distributed across all participants. This suggests that the developed learning media is capable of accommodating various levels of student ability, including those with low and moderate initial understanding. Furthermore, this evenly distributed improvement reflects that the features embedded in the media, such as concept visualization, interactive animations, and feedback-based quizzes, are effective in helping students understand the material gradually and comprehensively. Therefore, the increasing dominance of scores in the high category further strengthens the finding that the learning media has a consistent positive impact on improving students' understanding of ecosystem concepts.

The results of this study indicate that the Genially-based interactive learning media integrated with a digital-virtual environment has high quality in terms of validity, practicality, and effectiveness. The high validity of the media, based on evaluations by subject matter experts and media experts, demonstrates that the developed product meets the criteria of content feasibility, presentation, and visual design, making it suitable for use in the learning process. This is essential in development research, as the effectiveness of a learning media can only be validly interpreted if the product has undergone expert validation beforehand (Rukoyah & Bektiningsih, 2024).

In terms of effectiveness, the N-Gain value of 0.72, which falls into the high category, indicates that the media significantly improves students' understanding of ecosystem concepts. This result is supported by the prerequisite test showing that the data are normally distributed (Sig. > 0.05), confirming that the use of N-Gain analysis is statistically valid. Furthermore, the distribution of student scores, which shifted from the moderate to the high category, indicates that the improvement in learning outcomes occurred evenly and was not limited to a particular group of students. This finding suggests that the developed media is capable of accommodating various levels of student ability in understanding ecosystem concepts.

The improvement in conceptual understanding demonstrates that the use of Genially-based interactive media is effective in helping students comprehend abstract material. The visualizations, animations, and interactive simulations presented in the media enable students to observe relationships among ecosystem components in a more concrete and systematic manner. These findings are consistent with previous studies indicating that interactive multimedia learning media can enhance student learning outcomes and engagement (Martins et al., 2025; She et al., 2024). Moreover, the integration of visual and auditory elements in the media strengthens students' cognitive processes in understanding the material (Rahimi & Shute, 2021; Yuniarsih et al., 2025). Other studies have also shown that Genially-based media has a high level of effectiveness in improving the quality of multimedia-based learning (Rindawati et al., 2024).

When viewed from the perspective of the subject matter, ecosystem concepts are inherently complex as they involve interactions between biotic and abiotic

components as well as energy flow within a system. Without appropriate learning media, students tend to face difficulties in understanding these relationships. Therefore, the improvement in learning outcomes observed in this study indicates that the developed media successfully bridges these difficulties through structured visual presentations. This finding reinforces previous research stating that elementary school students' understanding of ecosystem concepts remains relatively low without adequate visual media support (Bambang et al., 2025; Yuliawati et al., 2024). In addition, the limitations of conventional teaching approaches also contribute to the low level of students' conceptual understanding (Sulysiah et al., 2024).

From a pedagogical perspective, the integration of a digital-virtual environmental approach in this media allows students to gain contextual learning experiences without the need for direct environmental observation. The media functions as a visual representation of the environment that helps students relate concepts to real-life situations. This finding aligns with previous studies indicating that environment-based approaches, whether direct or through visual representation, can enhance students' conceptual understanding (Akinsemolu & Onyeaka, 2025; Erfan et al., 2025). Furthermore, this approach supports students' knowledge construction through meaningful learning experiences (Wijanarko & Sujarwo, 2024; Elia et al., 2024) and contributes to increasing students' environmental awareness (Abdullah, 2024).

However, it is important to emphasize that the approach used in this study is not direct environment-based learning, but rather digital-virtual environment integration. The media serves as an alternative solution to overcome the limitations of field-based learning, such as time constraints, weather conditions, and safety considerations. Therefore, the developed media is more appropriately understood as a visual representation of the environment that supports contextual learning, rather than a substitute for direct real-world experiences.

The features within the media that contribute most significantly to the improvement of students' understanding include energy flow animations, interactive food chain simulations, visualization of ecosystem components, and feedback-based quizzes. These features not only enhance student engagement but also help them understand cause-and-effect relationships within ecosystems in a more systematic way. This confirms that learning becomes more effective when information is presented through the integration of visual and interactive elements, as emphasized in Mayer's multimedia learning theory (2021), without the need for lengthy theoretical explanations.

In addition, this study contributes to the achievement of global education goals, particularly Sustainable Development Goal 4 (SDG 4), which emphasizes the importance of quality education through the use of technology. The use of interactive digital media such as Genially has been shown to improve the quality of learning and expand access to meaningful learning experiences (Okulich-kazarin, 2025; Yang et al., 2025). This is further supported by studies highlighting the importance of technology integration in enhancing educational quality (Syafarudin & Ardiansyah, 2025). As a practical implication, the findings of this study suggest that Genially-based learning media with digital-virtual environmental integration can serve as an innovative solution for teachers in teaching abstract materials, particularly ecosystem topics.

Conclusion

The results of this study indicate that the Genially-based interactive learning media integrated with a digital virtual environmental context is highly valid, practical, and effective in improving fifth-grade elementary students' understanding of ecosystem concepts. The expert validation results show that the media achieved a score of 92.00% from the subject matter expert and 94.00% from the media expert, both categorized as highly valid. The practicality test results demonstrate that the media is highly practical, with teacher responses reaching 95.00% and student responses 90.00%. Furthermore, the effectiveness test reveals a significant improvement in learning outcomes, as indicated by an N-Gain value of 0.72 (high category), supported by the increase in the average pretest score from 50.00 to 86.00. These findings confirm that the integration of visualizations, animations, interactive simulations, and feedback-based quizzes within a digital virtual environmental representation effectively facilitates students' conceptual understanding. However, this media functions as a visual representation of the environment rather than a substitute for direct environmental observation. This study is limited to ecosystem material and a relatively small sample size; therefore, future research is recommended to develop similar media for other topics and to integrate more advanced Genially features, such as tracking individual student progress and adaptive feedback systems, to further enhance personalized learning in elementary education.

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Author Contributions

Designed the research, collected and analyzed the data, wrote the initial draft of the article manuscript, wrote the article

manuscript and conducted editing, M.; reviewed the research results, Y.R.; reviewed the research results, A.H.

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Conflicts of Interest
The authors declare that they have no conflict of interest related to this research.

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