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The Effect of Video-Based Learning on Elementary Students' Learning Outcomes in Ecosystem Topics

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Abstract: Understanding ecosystems is not only academically important but also practically valuable in fostering environmental awareness. Knowledge of ecosystem balance can cultivate a sense of responsibility toward environmental conservation and sustainability. This study aims to examine the effect of interactive video-based learning on elementary school students' learning outcomes in ecosystem topics. The research employed a Research and Development (R&D) approach using the ADDIE model and involved 30 fifth-grade students at SD Negeri Penuduan, Musi Banyuasin. Data were collected through expert validation, practicality testing, and pretest–posttest assessments, and were analyzed using N-gain scores and paired-sample t-tests. The validation results indicated that the developed learning videos were categorized as "very valid" in terms of content, language, and media aspects, with an average practicality level exceeding 90%. The pretest results showed an initial average score of 38, while the posttest average increased to 86.67, with an N-gain score of 0.78, which falls into the "high" category. The paired-sample t-test revealed a statistically significant improvement in students' learning outcomes ($p < 0.05$). These findings provide empirical evidence that interactive video-based learning is effective in improving elementary school students' learning outcomes and their understanding of ecosystem concepts.

Keywords: Ecosystem; Elementary education; Interactive video; Learning outcomes

Introduction

The development of science and technology in the 21st century has brought about significant changes across various sectors of life, including education. The demands of the globalization era position 21st-century skills like a higher-order thinking skills, problem-solving abilities, and creativity as essential competencies that students must acquire from an early age (Thornhill-Miller et al., 2023; Laar et al., 2020). In this context, improving students' learning outcomes has become a major focus in contemporary education, as it reflects not only the acquisition of knowledge but also students' ability to understand concepts, apply them in real-life situations, and make informed decisions related to global issues such as climate change, energy sustainability, and ecosystem conservation (Kelp et al., 2023). In the context of primary education, learning outcomes play a strategic role as a fundamental indicator of students' conceptual understanding and cognitive development. Elementary school students are at the concrete operational stage according to Piaget's theory of cognitive development, which requires learning experiences that are concrete, contextual, and directly observable in order for concepts to be well understood. However, the learning outcomes of Indonesian students in science subjects remain below the international average. For example, comparative studies based on PISA 2022 indicate that Indonesian students' achievement in science-related learning outcomes is still lower than that of several other countries, partly due to disparities in school facilities and curriculum support.

Furthermore, research at the elementary school level reveals that inappropriate learning materials, insufficiently contextualized instruction, and

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inadequate learning media are major factors contributing to low student learning outcomes in science learning (Prastiti & Adi, 2024). In response to these challenges, problem-based learning models that integrate local wisdom have been shown to be effective in improving students' learning outcomes and helping them connect scientific knowledge with everyday life (Restiani et al., 2024). These findings underscore the need for instructional strategies that foster improved learning outcomes from the primary school level. One approach that is widely believed to be effective in enhancing students' learning outcomes is video-based learning. Video media can concretize abstract concepts through the integration of visuals, narration, animation, and simulation, thereby facilitating comprehension and strengthening information retention an effect that aligns with experimental evidence on the modality effect, which demonstrates the superiority of combined visual and auditory information over written text alone (Haavisto et al., 2023). In addition, recent systematic reviews and meta-analyses indicate that videos, particularly when combined with interactive activities (e.g., pause-and-reflect tasks, guided inquiry, or virtual laboratories), yield learning outcomes comparable to or even better than hands-on experiments in certain elementary science contexts (Navarrete et al., 2025). From an instructional design perspective, video provides a multisensory learning experience that supports active learning by encouraging students to observe, analyze, and connect visual evidence with scientific concepts—an approach that aligns well with the characteristics of today's digital-native generation (Shao et al., 2024).

Within the Indonesian educational context, several studies published in JPPIPA have demonstrated the effectiveness of video-based media in students' learning outcomes and conceptual understanding, for instance, (Sukmawati et al., 2022) developed an online practicum video based on local wisdom and reported improvements in students' scientific learning outcomes following its implementation. Other studies have found that animated videos significantly enhanced students' learning interest and learning outcomes compared to conventional media. Natalina et al. (2024) produced a guided inquiry–based video tutorial as a practicum guide to strengthen students' understanding of plant tissue structure concepts. Similarly. Wardana & Adlini (2022) developed a 4D animated video on the human respiratory system that received positive responses from both students and instructional experts. Collectively, these findings suggest that video-based learning holds substantial potential for strengthening scientific learning outcomes at the primary school level. The ecosystem topic was selected as the focus of this study because of its close relevance to students' daily lives. Ecosystems encompass key concepts such as food chains, food webs, energy flow, and the impact of human activities on environmental balance. Nevertheless, this topic is often perceived as abstract and difficult to understand when presented solely through text or verbal explanations. For example, interactions between predators and prey or decomposition processes require clear visual representations for students to grasp the interrelationships among ecosystem components. Through video-based learning, these concepts can be presented in a more concrete, engaging, and memorable manner.

Furthermore, several studies have shown that video and interactive media presenting local examples (e.g., food webs within the school environment) can enhance students' conceptual understanding and Eco literacy without relying on coastal or specific geographic settings. The implementation of stop-motion animated videos has been reported to improve students' Eco literacy skills in ecosystem topics (Karuana et al., 2023). The development of interactive food-web media visualizing local environmental food chains has also strengthened students' understanding of inter-organism relationships and energy flow (Mukaromah et al., 2024). Needs analyses for virtual field trip–based media emphasize that when real field trips are difficult to conduct, virtual field trips and interactive videos serve as valid alternatives that effectively support observation and scientific discussion in the classroom, Therefore, integrating video-based learning that features local ecosystems is expected to combine authentic observational experiences with visual representations that reinforce students' scientific learning outcomes (Shanghao et al., 2025). Understanding ecosystems is not only academically important but also practically valuable in fostering environmental awareness. Knowledge of ecosystem balance can cultivate a sense of responsibility toward environmental conservation and sustainability. This aligns with the goals of scientific learning outcomes, which emphasize not only cognitive aspects but also the development of scientific attitudes and scientific skills.

An empirical study by Hanifha et al. (2023) found that the use of worksheets based on sociocentric issues significantly improved students' environmental awareness and scientific learning outcome. Similarly AlAli & Al-Barakat (2024) reported a strong positive correlation between scientific learning outcome and students' scientific attitudes when environmental learning approaches were applied. This research was conducted at SD Negeri Penuduan, Musi Banyuasin Regency, a public elementary school located in a rural area with diverse student characteristics. Preliminary observations indicated that science instruction at this school is still predominantly teacher-centered, relying mainly on lectures and textbooks as the primary learning resources, which limits students' opportunities for authentic exploration. Supporting facilities such as science laboratories and interactive learning media are also insufficient. These conditions have contributed to students' low scientific learning outcome, particularly in abstract topics such as ecosystems, where students often struggle to understand the interconnections among environmental components. This situation further emphasizes the urgency of implementing video-based learning media that can provide visual, engaging, and contextual learning experiences tailored to students' needs (Staneviciene & Žekienė, 2025).

Based on these considerations, this study aims to examine the effect of video-based learning on improving the scientific learning outcome of students at SD Negeri Penuduan in ecosystem learning. Through this approach, students are expected not only to understand ecosystem concepts cognitively but also to develop critical and analytical thinking skills and to cultivate ecological awareness from an early age. The findings of this study are expected to contribute to the development of more effective, innovative, and contextual science learning practices.

Method

Research Design

This study employed a Research and Development (R&D) approach, which aims to produce a new educational product or to improve an existing product through systematic development procedures. The study adopted the ADDIE development model—consisting of Analysis, Design, Development, Implementation, and Evaluation—as a framework to ensure that the research process followed appropriate methodological standards. The ADDIE model was selected due to its flexibility and its structured, systematic approach, which is particularly suitable for the development of technology-based instructional media. This model supports instructional designers in analyzing students' needs, designing relevant learning materials, developing effective learning videos, and implementing and evaluating their impact on improving elementary school students' scientific learning outcome in ecosystem material.

Research Site, Timeframe, Subjects, and Objects

This research was conducted at SD Negeri Penuduan, Musi Banyuasin Regency, from January to May 2025. The research subjects were fifth-grade students of SD Negeri Penuduan who actively participated in the learning process during the 2024/2025 academic year. The primary object of this study was the developed learning video, as well as students' learning activities while engaging with the video-based instruction.

Research Procedure

Analysis Phase

At this stage, the researcher identified the needs of science learning, particularly ecosystem content in Grade V elementary school, with a focus on students' scientific learning outcome, which includes the ability to understand scientific concepts, think critically, and relate knowledge to everyday life. The results of observations, interviews, and documentation indicated that students had low understanding of the interrelationships among ecosystem components, highlighting the need for innovative instructional media in the form of learning videos. The learning objectives were directed toward improving scientific learning outcome by fostering an understanding of the relationships between living organisms and their environment, in accordance with the characteristics of Grade V students at the concrete operational stage. The development of this media was supported by available resources, including technological equipment, expert support, and science learning materials from the IPAS Ecosystem chapter. Evaluation at the analysis stage was conducted through validation involving teachers, curriculum alignment, and observational data to ensure that objectives, target learners, and resources were aligned with instructional needs.

Design Phase

During the design phase, the researcher planned a learning video aimed at enhancing students' scientific learning outcome through activities such as observing food chains, identifying ecosystem components, and analyzing the impacts of environmental imbalance. Learning objectives were formulated based on the IPAS Learning Outcomes (Capaian Pembelajaran) for Phase C of the Merdeka Curriculum, emphasizing students' understanding of ecosystem structure, function, and the role of humans in environmental conservation. The media was designed for Grade V students at the concrete operational stage, making video-based visualization an appropriate instructional choice. Research instruments were also prepared, including expert validation sheets, observation sheets, response questionnaires, and pretest–posttest instruments to measure the effectiveness of the media. Evaluation at the design stage was conducted through consultations with teachers and experts to ensure alignment between the design, students' needs, and learning objectives.

Development Phase

In this phase, the researcher produced the learning video based on the designed storyboard, which included script writing, video recording, narration, and visual editing to ensure that the media was engaging and communicative. The initial product was validated by subject-matter experts, media experts, and language experts to assess content accuracy, language clarity, and visual presentation. After revisions, a one-to-one trial was conducted with three students of varying ability levels to obtain initial feedback on the clarity and attractiveness of the media. The results of expert validation and individual trials were then evaluated to refine the product before proceeding to small-group testing.

Implementation Phase

This phase involved small-group testing with several Grade V students to examine their responses to the learning video and to identify potential implementation barriers. Based on questionnaire results and teacher feedback, revisions were made to content, visual presentation, and technical aspects to enhance the effectiveness and practicality of the media. Evaluation at this stage focused on practicality, ease of use, attractiveness, and alignment with curriculum requirements and students' learning needs, ensuring that the media was ready for implementation in authentic classroom settings.

Evaluation Phase

The final phase involved field testing to assess the effectiveness of the learning video in improving students' scientific learning outcomes. The evaluation was conducted using pretests and posttests in real classroom conditions to measure improvements in students' understanding of ecosystem concepts, as well as students' and teachers' responses to the implementation of the media. Evaluation indicators included increased student participation, engagement in learning activities, and conceptual understanding, along with teacher feedback regarding usability and instructional suitability. The results of this evaluation indicated the extent to which the learning video effectively achieved the instructional objectives and served as a basis for further refinement before broader implementation.

Data Collection Techniques

This study employed multiple data collection techniques, both qualitative and quantitative, to obtain comprehensive findings. The techniques included observation, interviews, questionnaires, and tests. Observations and interviews were primarily used during the needs analysis stage to gather information on initial classroom conditions, teacher and student needs, and the instructional context. Questionnaires were administered at several stages, including needs analysis, expert validation, and product practicality testing. Tests were used during the evaluation phase to measure the effectiveness of the developed learning video, particularly in improving students' scientific learning outcomes on ecosystem content. The integration of these techniques was expected to provide a comprehensive overview of the quality and impact of video-based learning in elementary science education.

Data Analysis Techniques

Data processing was conducted in accordance with the type of data obtained. Qualitative data derived from observations and interviews were analyzed descriptively to support quantitative findings. Quantitative data, particularly from questionnaires, were analyzed using a Likert scale ranging from "very good" (score 5) to "very poor" (score 1). Scores obtained from expert validation sheets were calculated using the following formula:

$$X = \frac{\text{Score Obtained}}{\text{Score Ideal}} \times 100\% \quad (1)$$

The results were then categorized according to predetermined criteria, as shown in Table 1.

Table 1. Assessment criteria

Percentage Range (%)	Response Category	Validity Category	Practicality Category
0–20	Strongly Disagree	Very Invalid	Very Impractical
21–40	Disagree	Invalid	Impractical
41–60	Neutral	Fair	Fair
61–80	Agree	Valid	Practical
81–100	Strongly Agree	Very Valid	Very Practical

In this study, improvements in students' scientific learning outcomes were regarded as equivalent to improvements in learning outcomes. This assumption is based on the understanding that scientific learning outcomes at the elementary school level encompass not only the ability to read or write scientific terminology but also mastery of conceptual knowledge, scientific reasoning skills, and the ability to apply scientific concepts in everyday contexts. Therefore, students' learning outcomes in ecosystem content were used as indicators of their level of scientific learning outcomes. Accordingly, the test instruments were designed to measure both conceptual understanding and scientific thinking skills. The tests were administered in two stages: a pretest before the implementation of video-based learning and a posttest after the instructional intervention. The difference between pretest and posttest scores was analyzed using the normalized gain (N-gain) formula to determine the magnitude of learning improvement, which also reflects improvements in students' scientific learning outcomes. To calculate the N-gain score, the following formula was used:

$$N_{gain} = \frac{S_{posttest} - S_{pretest}}{S_{maximum} - S_{pretest}} \quad (2)$$

Description:
N-gain = normalized gain score
Pretest score = average pretest score
Posttest score = average posttest score
Maximum score = maximum possible score

The N-gain values were classified into three categories, as shown in Table 2.

Table 2. N-gain score criteria

N-gain Score	Category
> 0.70	High
0.30–0.70	Medium
< 0.30	Low

Furthermore, to determine whether the improvement in learning outcomes before and after the use of the learning media was statistically significant, a paired sample *t*-test was conducted at a significance level of 0.05. The statistical hypotheses were formulated as follows: H_0: There is no significant difference in learning outcomes before and after the use of the learning media; H_1: There is a significant difference in learning outcomes before and after the use of the learning media.

Result and Discussion

Product Development Results

The developed product is not merely a learning video but an interactive learning video. The video incorporates several interactive features that can be used by students to support their learning process, ultimately contributing to improvements in learning outcomes, scientific learning outcomes, and students' scientific attitudes. Figures 2–5 present several visual displays illustrating the results of the product development.

Figure 1. Cover display

Figure 2. Menu display

Figure 3. Content display

Figure 4. Quiz display

After the product development process was completed, the learning video underwent a series of expert validation procedures prior to further testing stages. Expert validation was conducted to evaluate three main aspects: language, media, and content (material). The results of the expert validation are presented as follows.

Expert Validation Results

Language Expert Validation

Table 3. Language expert validation results

Aspect	Obtained Score	Ideal Score	Percentage (%)	Average Score (%)
Language Appropriateness	13	15	86.60	88.40 (Very Valid)
Clarity and Readability	13	15	86.60	
Accuracy	23	25	92	

Based on the language expert validation results, the ecosystem learning video developed to enhance students' scientific learning outcomes received highly satisfactory evaluations. In the language appropriateness aspect, the video achieved a score of 13 out of 15 (86.60%), indicating that word choice, sentence structure, spelling, and grammar were well constructed and effectively supported content comprehension. The clarity and readability aspect also obtained a score of 13 out of 15 (86.60%), demonstrating that narration, text, and visual elements were clear and easy to understand, facilitating students' information absorption. Meanwhile, the accuracy aspect achieved the highest score, 23 out of 25 (92%), confirming the scientific accuracy, relevance, and curriculum alignment of the video content. Overall, these results indicate that the learning video meets excellent linguistic standards in terms of both scientific accuracy and readability.

Media Expert Validation

Table 4. Media expert validation results

Aspect	Obtained Score	Ideal Score	Percentage (%)	Average Score (%)
Visual Design	12	15	80	87.47 (Very Valid)
Functionality	14	15	93.30	
Consistency and Aesthetics	9	10	90	
Usefulness	13	15	86.60	

The media expert validation results indicate that the ecosystem learning video achieved very high-quality standards. In the visual design aspect, the video scored 12 out of 15 (80%), demonstrating effective use of color schemes, layout, typography, image quality, and animation. Attractive visual design plays a crucial role in enhancing student focus, reducing cognitive load, and strengthening visual literacy. The functionality aspect achieved an outstanding score of 14 out of 15 (93.30%), indicating smooth video playback, clear audio quality, synchronized narration, and seamless navigation without technical issues. The consistency and aesthetics aspect scored 9 out of 10 (90%), reflecting strong coherence between visual style, narration, and content presentation, resulting in a professional and integrated learning experience. Finally, the usefulness aspect scored 13 out of 15 (86.60%), confirming that the video aligns well with curriculum demands, supports problem-solving activities, and encourages critical thinking skills. Overall, scores above 80% across all aspects demonstrate that the learning media meets rigorous quality standards and is highly suitable for classroom use.

Content (Material) Expert Validation

Table 5. Content expert validation results

Aspect	Obtained Score	Ideal Score	Percentage (%)	Average Score (%)
Curriculum Alignment	18	20	90	90.66 (Very Valid)
Relevance to Student Characteristics	14	15	93.30	
Completeness and Clarity	9	10	90	
Innovation	8	10	80	
Instructional Impact	10	10	100	

The content expert validation results indicate that the ecosystem learning video possesses very high quality and is highly suitable for instructional use. Curriculum alignment achieved a score of 90%, relevance to student characteristics reached 93.3%, completeness and clarity scored 90%, innovation scored 80%, and instructional impact reached a perfect score of 100%. These results confirm that the content is curriculum-aligned, easy to understand, and has strong potential to enhance scientific learning outcomes and student engagement. Nevertheless, the content expert recommended several improvements, including numbering learning objectives, adding real-life images, preparing offline student worksheets, and including enrichment materials such as decomposition process videos with clearly cited sources. All suggestions were incorporated through revisions to ensure the video became more comprehensive, engaging, and aligned with effective instructional standards. Overall, all three experts agreed that the developed product was valid, with several refinement suggestions implemented to improve its quality. After being declared valid, the product proceeded to the practicality testing stage.

Practicality Testing

Practicality testing was conducted to assess the ease of use, implement ability, and acceptability of the ecosystem learning video as an instructional medium. The primary purpose of this test was to evaluate how effectively students could use the developed video without encountering significant technical or pedagogical difficulties. This stage provided insights into operational ease, clarity of usage instructions, visual attractiveness, content relevance, and the video's usefulness in supporting ecosystem concept understanding and improving scientific learning outcomes. Practicality testing was conducted in two stages: individual testing (one-to-one) and small group testing.

Individual Testing

Table 6. Individual practicality test results

Name	Usage Instructions	Video Content	Language in the Video	Video Visualization	Suitability and Practicality	Total Score	Ideal Score	Practicality Score (%)	Remarks
DMF	5	5	9	19	10	48	50	96	Very Practical
ASRF	5	5	10	18	10	48	50	96	Very Practical
ZZ	4	5	10	20	10	49	50	98	Very Practical

All three participants (DMF, ASRF, and ZZ) provided consistently high scores across all assessed aspects, including usage instructions, content, language, visualization, and overall suitability and practicality. The visualization aspect received perfect scores from all evaluators, highlighting the strong visual quality of the media. Final practicality scores reached 96% for DMF and ASRF, and 98% for ZZ, all categorized as Very Practical.

Small Group Testing

Table 7. Small group practicality test results

Name	Usage Instructions	Video Content	Language in the Video	Video Visualization	Suitability and Practicality	Total Score	Ideal Score	Practicality Score (%)	Remarks
MAP	4	4	9	17	10	44	50	88	Very Practical
NYP	4	5	10	18	10	47	50	94	Very Practical
JF	4	5	9	20	10	48	50	96	Very Practical
FYD	5	4	9	19	9	46	50	92	Very Practical
IAN	5	5	9	19	10	48	50	96	Very Practical
KF	5	5	10	18	10	48	50	96	Very Practical
MA	4	5	10	20	10	49	50	98	Very Practical
SFD	4	4	9	18	9	44	50	88	Very Practical

The results from eight respondents revealed consistently high evaluations across all assessed aspects. The average practicality score reached approximately 93.50%, with individual scores ranging from 88% to 98%, all categorized as Very Practical. Visualization emerged as a key strength, with most respondents awarding perfect scores. Content clarity and language quality also received high ratings, indicating strong relevance and comprehensibility. Overall, the developed product demonstrated excellent practicality and was deemed ready for full-scale testing with all Grade V students at SD Negeri Penuduan.

Effectiveness Testing

Effectiveness testing began with the administration of a pretest to all students before exposure to the interactive learning video. This initial test aimed to identify students' baseline knowledge and understanding of ecosystem concepts.

Pretest Results

Table 8. Pretest results summary

Score Interval	N- Student	Percentage (%)	Category
81–100	0	0	Very Good
61–80	1	3.33	Good
41–60	17	56.67	Enough
21–40	10	33.33	Poor
0–20	2	6.67	Very Poor

The pretest results indicate that students' initial understanding prior to the intervention was relatively low. Of the 30 students, none achieved the "Very Good" category (81–100%), and only one student (3.33%) reached the "Good" category (61–80%). The majority of students (56.67%) fell within the "Fair" category (41–60%), while 33.33% were categorized as "Poor" and 6.67% as "Very Poor." These results demonstrate that most students lacked strong conceptual understanding before the intervention.

Posttest Results

Table 9. Posttest results summary

Score Interval	N- Student	Percentage (%)	Category
81–100	27	90	Veery Good
61–80	3	10	Good
41–60	0	0	Enough
21–40	0	0	Poor
0–20	0	0	Very Poor

The posttest results demonstrate a substantial improvement in students' Scientific Learning Outcome following the use of the ecosystem learning video. Of the 30 students, 27 (90%) achieved scores in the "Very Good" category, while the remaining 3 students (10%) reached the "Good" category. No students fell into the lower categories. These findings indicate that the developed learning video was highly effective in enhancing students' understanding of ecosystem concepts and Scientific Learning Outcome.

N-Gain Analysis

Table 10. Comparison of pretest and posttest scores

Name	Pretest	Posttest	N-Gain	Category
AN	30	100	1.00	High
RY	30	90	0.86	High
SDH	30	90	0.86	High
DTY	30	90	0.86	High
PRM	40	90	0.83	High
FA	30	90	0.86	High
LKS	40	90	0.83	High
WND	30	90	0.86	High
TMR	30	80	0.71	High
VT	50	80	0.60	Mid
RSN	40	80	0.67	Mid
AYU	60	80	0.50	Mid
DN	40	80	0.67	Mid
JLI	40	70	0.50	Mid
KML	50	60	0.20	Low
ZR	40	100	1.00	High
BDA	40	90	0.83	High
GRP	40	90	0.83	High
IMN	30	90	0.86	High
CJ	40	90	0.83	High
EKO	50	100	1.00	High
MIA	50	90	0.80	High
NJO	50	90	0.80	High
SIS	40	90	0.83	High
UDN	40	90	0.83	High
HDA	30	90	0.86	High
GR	30	90	0.86	High
XSA	40	90	0.83	High
YNI	20	80	0.75	High
AHM	20	80	0.75	High
Total	1140	2600		
Average	38	86.67	0.78	High
Minimum	20	70		
Maximum	60	100		

The comparison results show a significant improvement in learning outcomes. The average pretest score increased from 38 to 86.67 in the posttest. The calculated average N-gain score was 0.78, which falls into the High category. Prior to the intervention, student scores ranged from 20 to 60, indicating low to moderate understanding. After the intervention, posttest scores ranged from 70 to 100, demonstrating substantial and consistent improvement across students. Detailed analysis revealed that 24 students (80%) achieved high N-gain scores (≥ 0.70), including five students who attained a perfect N-gain score of 1.00. Five students (16.67%) demonstrated moderate improvement, while only one student (3.33%) showed low improvement. These results confirm the strong effectiveness of the intervention.

Paired Sample t-Test Results

Table 11. Paired samples test results

		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
					Lower	Upper			
Pair 1	Before Intervention - After Intervention	-49.33	13.37	2.44	-54.32	-44.34	-20.20	29	.000

The paired-sample *t*-test results indicate a mean difference of −49.333, reflecting an average increase of 49.333 points in student learning outcomes following the intervention. The standard deviation (13.37) and standard error (2.44) indicate consistent score differences among students. The 95% confidence interval ranged from −54.32 to −44.340, excluding zero, which confirms a statistically significant difference. The obtained *t* value of −20.205 with 29 degrees of freedom yielded a significance value (p = 0.000), which is far below the 0.05 threshold. These results confirm a highly significant difference between pretest and posttest scores. Therefore, it can be concluded that the use of interactive video-based learning on ecosystem content has a strong and significant effect on improving students' learning outcomes and scientific learning outcomes.

Discussion

The findings of this study convincingly demonstrate that the use of interactive learning videos on ecosystem content has a significant positive impact on improving students' learning outcomes and scientific learning outcomes. The increase in the average score from 38 in the pretest to 86.67 in the posttest, accompanied by an N-gain value of 0.78 classified as high, indicates that this learning media effectively facilitates the process of knowledge construction compared to conventional instruction. This result is further strengthened by the paired-samples *t*-test, which yielded a significance value of 0.000 ($p < 0.05$), confirming that the difference between pre-intervention and post-intervention achievement was not coincidental but rather the result of systematically designed instructional media aimed at enhancing conceptual understanding and students' scientific thinking skills. This success can be explained through the lens of cognitive and constructivist learning theories, in which students are not passive recipients of information but actively interact with learning materials through rich visual, auditory, and interactive experiences (Mayer, 2024) emphasized that multimedia learning principles optimize information processing by engaging both verbal and visual channels simultaneously, thereby improving retention and knowledge transfer. These findings align with the review by Fiorella & Mayer (2018) which highlights the importance of segmentation, generative prompts, and dynamic representations in facilitating the development of stable cognitive schemas.

Furthermore, instructional video design guidelines proposed by van der Meij and colleagues indicate that applying eight design steps, including visual mapping, step differentiation, and clear narrative structure, can enhance student motivation, task performance, and retention (Meij & Hopfner, 2022). Recent meta-analytic evidence also reinforces that videos incorporating interactive features such as quizzes and feedback produce significantly greater learning gains than non-interactive videos, although their effectiveness may decrease if interactions are presented without adequate pauses due to split-attention effects (Ploetzner, 2022). Consistent with the findings of this study, international empirical evidence suggests that interactive features embedded in learning videos, such as pop-up questions, learner controls (pause/slow motion), segmentation, and short tasks, play a crucial role in increasing student engagement and learning outcomes. For instance, Haagsman, Scager, Boonstra, and Koster found that the inclusion of pop-up questions in preparatory videos for flipped classrooms significantly improved students' learning achievement in molecular biology topics (Haagsman et al., 2020; Ljubojević et al., 2025). Similarly, the classic study by Schwan and Riempp demonstrated that interactive videos allowing learners to control playback speed and navigation significantly enhanced procedural skill acquisition and retention compared to non-interactive videos, while also emphasizing the need for interface designs that minimize cognitive load when adding interactive features (Schwan & Riempp, 2004).

On the other hand, comparative studies examining video versus printed textbooks indicate that the added value of video depends on the quality of interactivity: well-designed interactivity can enhance motivation and task performance, whereas poorly synchronized or excessive interactivity may fragment learners' attention. These findings are comprehensively discussed by Merkt, Weigand, Heier, and Schwan in their analysis of the role of interactive features in video-based learning (Merkt et al., 2011; Galatsopoulou et al., 2022). Collectively, this body of evidence explains why the interactive learning video developed in this study produced substantial learning gains and a high N-gain score. Mechanisms such as the testing effect (embedded questions), cognitive load reduction through segmentation, and activation of generative processing through short tasks collectively support the transformation of declarative knowledge into deeper, measurable understanding (Wu et al., 2025). The results of this study are also consistent with findings from local research. For example, Mantoviana et al. (2023) reported improved conceptual understanding following the development of Flash-based interactive multimedia for biology instruction, supporting the conclusion that interactive media enhance science concept mastery. Similarly Sari et al. (2023) demonstrated that H5P-based interactive media effectively strengthened critical thinking skills and conceptual understanding among pre-service teachers, aligning with the generative processing and immediate feedback mechanisms present in the interactive video developed in this study. Additionally, Adhana & Andriani (2024) found that problem-based learning–oriented interactive multimedia significantly improved learning outcomes, reinforcing the argument that integrating instructional strategies (e.g., PBL) with interactive features amplifies the effectiveness of video-based learning. Within the instructional theory framework applied in this study, Mulyani et al. (2024) reported that video designs based on Gagné's instructional theory resulted in improved student learning outcomes in informatics education, further confirming that systematic instructional design plays a critical role in achieving high N-gain scores.

Beyond learning outcomes, this study highlights the contribution of interactive learning videos to strengthening scientific learning outcomes, which encompass understanding scientific concepts, relating them to real-world phenomena, and making science-based decisions. Scientific learning outcomes are key 21st-century competencies that require not only content knowledge but also critical thinking and problem-solving skills. Interactive media have proven effective in facilitating all three dimensions of scientific learning outcomes—concept, process, and context—through engaging, relevant, and applied content delivery.

For instance, Rusdawati & Eliza (2022) showed that science literacy–oriented learning videos for early childhood education enhanced student engagement and conceptual understanding. Auliaty et al. (2021) also reported high validity and practicality in developing science literacy–based interactive media for fourth-grade elementary students, supporting improvements in scientific learning outcomes. Studies on Powtoon-based multimedia for sound wave topics similarly reported significant N-gain improvements in students' scientific learning outcomes. Moreover, Novianti et al. (2022) and Putri et al. (2025), developed interactive multimedia teaching materials for fifth-grade science content that were validated as practical and effective in supporting conceptual understanding. These local findings are consistent with the results of the present study: when instructional media are designed to be interactive, contextual, and supportive of exploration and reflection, students' scientific learning outcomes improve substantially, as evidenced by high N-gain scores and a large proportion of students achieving the "very good" category.

The strength of this media also lies in its visual quality and ease of use, which were rated as highly practical by both students and teachers (Jannah et al., 2025). Practicality test results indicated average scores exceeding 90%, with visualization receiving the highest ratings. Attractive visualizations not only enhance learning enjoyment but also reduce students' cognitive load, allowing them to focus more effectively on conceptual understanding. emphasized that effective visual design in multimedia (Gebremariam & Weldeyohannes, 2025) emphasized that effective visual design in multimedia learning plays a critical role in facilitating comprehension of complex concepts, such as ecosystems (Witt et al., 2024), which involve multiple components and interactions. Overall, the findings of this study reinforce the view that interactive learning videos represent an effective instructional innovation for improving learning outcomes and scientific learning outcomes among elementary school students. These results carry important implications for educational practice, particularly in science education, which often involves abstract concepts. Teachers can utilize interactive videos as an alternative or complementary approach to conventional methods to create more contextual, engaging, and meaningful learning experiences. Nevertheless, despite the highly positive outcomes, several improvement suggestions from validators—such as adding enrichment materials, real-life images, and offline worksheets—should be considered to further enhance the comprehensiveness and adaptability of the media across diverse instructional contexts. Future research involving larger samples and longer intervention periods is recommended to evaluate long-term impacts on higher-order thinking skills, such as problem-solving and scientific argumentation, to gain deeper insights into the contribution of interactive video-based learning to scientific learning outcomes development (Pellas, 2025; Yoon et al., 2021).

Conclusion

This study demonstrates that the use of interactive learning videos on ecosystem content significantly improves elementary school students' learning outcomes and scientific learning outcomes. Students' average scores increased from 38 in the pretest to 86.67 in the posttest, with an N-gain score of 0.78 categorized as high. The paired-sample *t*-test yielded a significance value of 0.000 ($p < 0.05$), confirming a statistically significant difference between pre-intervention and post-intervention achievement. Expert validation results for language, media, and content categorized the product as very valid, while practicality testing yielded average scores above 90%, indicating that the media is highly practical for classroom implementation. These findings provide strong empirical evidence that integrating interactive learning videos is an effective approach to strengthening ecosystem concept understanding and enhancing elementary students' scientific thinking skills and scientific learning outcomes.

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