



## Scientific-based Digital Storytelling to Enhance Science Literacy and Environmental Awareness in Junior High School Students

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### Abstract

This study explores the use of scientific-based digital storytelling to enhance science literacy and environmental awareness among junior high school students. Using a Research and Development (R&D) approach guided by the Successive Approximation Model (SAM), the media was developed and evaluated through two phases: Alpha testing using a one-group pretest-posttest design, and Beta testing using a quasi-experimental design. A total of 89 seventh-grade students from a coastal school in South Sulawesi, Indonesia, participated. The digital storytelling media, adapted from a local fable, combined narrative elements with real environmental data to engage students in observation, analysis, and reflection. Findings revealed significant improvements in students' science literacy and environmental awareness, particularly in data interpretation and issue recognition. Although the treatment group reached the minimum passing criteria for science literacy, further pedagogical support is needed for mastery. Student and teacher responses indicated that the media was engaging, practical, and accessible through mobile devices. These results suggest that digital storytelling, when integrated with real-world content and structured pedagogy, can be a powerful tool for promoting multiliteracies and environmental responsibility. The study supports the integration of narrative-based digital media in science education to foster critical thinking and meaningful learning.

**Keywords:** digital storytelling, science literacy, environmental awareness, Successive Approximation Model (SAM)

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## INTRODUCTION

Environmental issues such as climate change, pollution, deforestation, and biodiversity loss, are some of the most pressing global challenges of our time. To affectively address these complex problems, we need not only technological solutions but also a population that is scientifically literate and environmentally aware. In particular, it is crucial for younger generations to be equipped with the knowledge and skills to understand scientific data and act responsibly towards the environment (Alagoz & Akman, 2016).

However, evidence suggests that this goal remains unmet in many regions. The PISA 2022 results indicate that Indonesian students continue to perform below the OECD average in science literacy, demonstrating weaknesses in interpreting scientific data and analyzing environmental issues (OECD, 2023a). Similar findings have been reported by Adnan et al. (2021), who note that Indonesian students, especially at the junior high school level, struggle significantly with organizing and interpreting quantitative information. In Indonesia, the integration of environmental literacy into science education remains fragmented. Although the *Kurikulum Merdeka* emphasizes project-based and contextual learning, implementation challenges persist, especially in rural schools where access to

digital resources is limited. These concerns have prompted international calls to strengthen science education within the broader framework of sustainability (Kumar et al., 2024).

Recognizing these global challenges, the OECD has expanded its assessment frameworks for PISA 2025 to include not only science literacy but also environmental awareness, concern, and agency (OECD, 2023b). Despite this, Indonesia's performance remains concerning, highlighting the urgent need for innovative educational interventions (Sukma et al., 2020; Sugiarti et al., 2021).

One effective approach is the implementation of digital storytelling, a teaching technique that merges storytelling elements with interactive digital media. Studies have shown that digital storytelling can enhance student engagement, support the understanding of scientific concepts, and bridge abstract data with real-world environmental contexts (Robin, 2016; Smeda et al., 2014). By embedding environmental issues within emotionally resonant narratives, digital storytelling not only enhance cognitive understanding but also encourages emotional investment and promote pro-environmental action (Marsico et al., 2019; Andriopoulou et al., 2022).

Science literacy, in this context, refers to the ability to apply scientific knowledge to real-life situations, interpret data, and make evidence-based decisions (OECD, 2023b; Laugksch, 2000). Environmental awareness, meanwhile, involves recognizing ecological interdependencies and understanding the consequences of human actions on natural systems (Leiserowitz, 2006; Kalnins & Laukkanen, 2020). Both competencies are crucial for equipping students to critically assess and respond to environmental issues.

Digital storytelling is uniquely suited to support both domains. As shown by Sadik (2008) and Yang & Wu (2012), integrating narrative with scientific inquiry encourages deeper learning and supports the development of critical thinking. When paired with scientific approaches such as observation, experimentation, and analysis, storytelling becomes a powerful instructional tool that can make abstract environmental data more relatable and actionable.

In summary, the integration of digital storytelling with scientific learning processes present a compelling approach to enhancing science literacy and environmental awareness. By incorporating real data into narrative structures, students are encouraged not only able to grasp complex scientific concepts, but also develop a sense of concern for these issues and are motivated to take action. This study explores the development and implementation of such a digital storytelling-based learning model to address science and environmental literacy among junior high school students. As such, the objective of this study is to design, implement, and evaluate a scientific-based digital storytelling medium to enhance junior high school students' science literacy and environmental awareness among junior high school students.

## **METHODS**

This study employed a Research and Development (R&D) approach following the Successive Approximation Model (SAM) to design and evaluate a scientific-based digital storytelling media aimed at enhancing students' science literacy and environmental awareness. Participants were 89 seventh-grade students (ages 11–13) from SMP Negeri 2 Galesong Selatan, a coastal junior high school in South Sulawesi, Indonesia. Three out of eight available classes (VII A, VII B, VII C) were selected using cluster random sampling. Class VII A participated in Alpha testing using a one-group pretest-posttest design, while Classes VII B and VII C were assigned to the treatment and control groups respectively for the Beta test using a quasi-experimental design.

Science literacy and environmental awareness were assessed using researcher-developed instruments based on the PISA 2022 and 2025 frameworks. Science literacy focused on students' ability to interpret data and scientific evidence, with items requiring students to interpret a line chart on plastic waste in oceans and analyze the relationship between carbon emission trends and deforestation rates. Environmental awareness was measured through indicators of awareness, concern, and agency toward environmental issues. The intervention followed a Problem-Based Learning (PBL) model using teacher-developed digital storytelling media. The story, adapted from a local fable (Kancil), incorporated environmental issues and scientific data to guide students through stages of observation, analysis, and communication. Each implementation session lasted 90 minutes.

In this study, the researcher also served as the classroom teacher who implemented the digital storytelling intervention and facilitated all learning activities. To maintain objectivity in classroom observation, two mathematics teachers from the same school were assigned as independent observers. Their role was to document student responses, classroom dynamics, and the practicality of media implementation. Data were collected using pretest and posttest instruments, structured questionnaires, classroom observations, and interviews, all of which were validated by two content experts. Quantitative data were analyzed using SPSS version 25, employing descriptive and inferential statistics.

## **RESULTS & DISCUSSION**

### ***Results***

#### *Digital Storytelling Media Overview*

The digital storytelling media developed for this study is presented in the form of an interactive picture book as seen in Figure 1, structured using Storyline 3 and designed to be accessible to students online via mobile devices. The narrative, titled "Kancil and the Dying Forest," follows the journey of Kancil, a clever forest animal who witnesses widespread environmental damage. As he travels to seek help from the lion, the forest king, Kancil encounters various animals suffering the consequences of human actions: a shrinking giraffe due to deforestation, a starving crocodile in a polluted river, and flightless birds affected by air pollution. The lion, hiding from the noise of industry, directs Kancil to the forest fairy, who gives him a magical seed that eventually restores the forest's balance. The story concludes with a powerful reflection: humans now experience the same environmental degradation once faced by animals, and nature may no longer come to their rescue.

Each segment of the story is paired with a live data link relevant to the environmental issue presented—for instance, a link to deforestation statistics when Kancil meets the giraffe. These links direct students to real-world data sources where they are asked to observe, analyze, and interpret environmental data, then draw their own conclusions. This approach allows students to connect the narrative to actual scientific information, supporting the development of data interpretation skills, science literacy, and environmental awareness through an emotionally engaging and contextually grounded experience.

During the implementation phase, a scientific approach was applied to strengthen student engagement and comprehension of the digital storytelling content. This process followed six stages. First, students began by observing the environmental damage shown in the story. Next, they generated questions about the causes and consequences of the issues presented, such as deforestation, water pollution, and air pollution. They then observed real-world environmental data—linked within the media—covering forest loss, plastic

waste, and pollution. In the reasoning stage, students interpreted these data, identifying patterns and cause-effect relationships. Subsequently, they organized their findings into articles, tables, or infographics and transformed them into graphs, enhancing their ability to represent information visually. Finally, students communicated their conclusions by explaining the graphs and environmental data they had worked with. This integrated process not only deepened scientific understanding but also nurtured students' capacity to critically interpret and share environmental information.



Figure 1 Set of Visual Prototype Media

*Validation Results*

The validation process of the digital storytelling media involved expert reviews in two key areas: media design and content quality. Based on the Tabel 1, in the first validation round, both aspects were categorized as not valid, indicating several shortcomings in visual design, animation fluency, clarity of information, and alignment with curriculum goals. Based on expert feedback, several revisions were made, including improving visual layout, refining font size and color contrast, enhancing scientific accuracy, and ensuring alignment with environmental education standards.

After these revisions, the second validation round showed substantial improvements. The Wilcoxon Signed Rank Test results indicated a statistically significant difference between the first and second validations ( $p < 0.001$ ), confirming that the revisions successfully addressed the issues identified in the initial review. The final version of the media was therefore declared valid and suitable for classroom use.

These findings support Chen, Liu, and Cheng (2023), who emphasize the importance of visual fluency and media quality in sustaining learner engagement. In addition, Davey and Benjaminsen (2021) highlight that effective digital storytelling must integrate well-organized content, reliable data sources, and coherent narrative structures to support deep learning—elements that were successfully improved during the validation process.

Table 1. Results of Validation

Aspect	1 <sup>st</sup> Validation	2 <sup>nd</sup> Validation	Asymp. Sig. (2-tailed)
Media	63 (Invalid)	84 (Valid)	0.000
Content	64 (Invalid)	83 (Valid)	0.000

*Alpha Testing Results*

The alpha testing was conducted with Class VII A (n = 31) using a one-group pretest-posttest design to evaluate the preliminary effectiveness of the validated digital storytelling media. The results demonstrate significant improvements in students' science literacy, environmental awareness, and engagement levels.

As shown in Table 2, the post-test mean score for science literacy increased compared to the pretest, although it did not exceed the minimum passing score (KKTP) of 70. However, the statistical analysis ( $p = 0.873$ ; Cohen's  $d = 0.29$ ) indicates that while progress was observed, it was not statistically significant in this phase. The absence of statistical significance ( $p = 0.873$ ) despite observable mean gains suggests that while digital storytelling improves engagement, it may not directly transfer to data interpretation skills without scaffolding. This finding aligns with Robin (2008) and Göksün & Gürsoy (2022), who emphasized that digital narratives require guided facilitation to deepen conceptual understanding. This finding is consistent with Robin (2008) and Göksün & Gürsoy (2022), who noted that digital storytelling supports engagement but may require teacher scaffolding to support comprehension of technical content.

Table 2. One Sample t Test of Variable at Alpha Test

Variable	Test Value	Mean	p value	Cohen's d	Effect Size
Student' Science Literacy	70	69.71	0,873	0.29	
Students' Awareness	70	79.77	0.000	2,145	
Students' responses	70	78.90	0.000	2.395	

In contrast, environmental awareness showed a statistically significant improvement ( $p < 0.001$ ), with a very large effect size (Cohen's  $d = 2.145$ ), as detailed in Table 3. This suggests that the narrative elements of the media successfully cultivated students' critical awareness and emotional connection to environmental issues, in line with findings by Andriopoulou et al. (2022).

Table 3. Results of Observation of Learning Implementation and Teacher responses at Class VIIA

Data	Teacher 1	Teacher 2	Average
Observation of Learning Implementation	99	103	101 (Good)
Teacher responses	70	68	69 (Very Good)

Additionally, student feedback on the media was highly positive, with an average response well above the threshold ( $p < 0.001$ ; Cohen's  $d = 2.395$ ). Teacher observations and response scores (see Table 2) confirmed the media's practicality and ease of use in the classroom, with agreement levels in the "good" to "very good" range. These findings affirm the potential of digital storytelling to support constructivist learning environments, as supported by Smeda et al. (2014).

Further analysis using a paired sample t-test (Table 4) confirmed statistically significant gains between the pretest and post-test for both science literacy and environmental awareness ( $p < 0.001$ ), with very large effect sizes, indicating a strong initial impact of the media on learning outcomes.

Table 4. Paired Sample t Test of Variable at Alpha Test

Variables	Mean	p value	Cohen's d Effect Size
Science Literacy Pretest of Class VIIA	41.42	0.000	5.749
Science Literacy Posttest of Class VIIA	69.71		
Environmental Awareness Pre-Survey of Class VIIA	47.35	0.000	4.892
Environmental Awareness Post-Survey of Class VIIA	79.77		

*Beta Testing Results*

The beta testing phase was conducted to evaluate the effectiveness of the scientific-based digital storytelling media in a quasi-experimental setting. Two seventh-grade classes participated: Class VII B served as the treatment group and received instruction using the digital storytelling media, while Class VII C acted as the control group and received conventional, text-based instruction. This phase was designed to assess the media's impact on science literacy and environmental awareness through a comparative approach.

A paired-sample t-test showed that the treatment group experienced a statistically significant improvement in science literacy after the intervention, with a large effect size (see Table 5). This indicates that the media was successful in supporting students' ability to read and interpret scientific data, a core component of science literacy as defined by the PISA framework. The multimodal nature of the media and its contextual narrative appear to have enhanced conceptual understanding, as also supported by Robin (2008) and Yang and Wu (2012), who found that digital storytelling can enrich engagement and retention of scientific content.

Table 5. Paired Sample Test of Variables at Beta Test

Variables	Mean	p value	Cohen's d Effect Size
Science Literacy Pretest of Treatment Group	38.10	0.000	5.749
Science Literacy Posttest of Treatment Group	70.00		
Environmental Awareness Pre-Survey of Treatment Group	46.30	0.000	-
Environmental Awareness Post-Survey of Treatment Group	79.76		

In terms of environmental awareness, students in the treatment group also showed a significant increase in their post-survey scores, with a large effect size (also presented in Table 5). The story's focus on relatable ecological problems and its integration with real data sources may have contributed to a stronger emotional and cognitive response. This supports the findings of Andriopoulou et al. (2022), who emphasized that environmental narratives in digital storytelling foster critical thinking and empathy toward ecological issues.

A comparison of the post-test results between the treatment and control groups further confirmed the media's impact. As shown in Table 6, students who used the digital

storytelling media scored significantly higher than those in the control group on both science literacy and environmental awareness measures. The normalized gain (N-Gain) for both variables was also greater in the treatment group, indicating more substantial learning progress. These findings underscore the comparative advantage of digital storytelling in facilitating meaningful, data-driven learning experiences.

Table 6. Independent Sample Test of Variables at Beta Test

Variables	Mean	p value	Cohen's d Effect Size
Science Literacy Posttest of Treatment Group	70.00	0.000	1.809
Science Literacy Posttest of Control Group	55.03		
Environmental Awareness Post-Survey of Treatment Group	79.76	0.000	3.950
Environmental Awareness Post-Survey of Control Group	55.78		
N Gain of Science Literacy Pretest and Posttest of Treatment Group	0.53	0.000	1.222
N Gain of Science Literacy Pretest and Posttest of Control Group	0.30		
N Gain of Environmental Awareness Pre-Post-Survey of Treatment Group	0.62	0.000	4.417
N Gain of Environmental Awareness Pre-Post-Survey of Control Group	0.52		

Although several effect sizes (e.g., Cohen's  $d = 4.417$ ) were categorized as extremely large, these may indicate a ceiling effect caused by small sample variance rather than unusually high treatment impact. According to Cohen (1988), values above 0.8 represent large effects, suggesting strong educational relevance despite statistical inflation.

However, it is important to note that while the treatment group's post-test mean score for science literacy reached the minimum passing standard (KKTP), it did not exceed it in a statistically significant way (see Table 7). The corresponding effect size was negligible, suggesting a plateau in performance once students approached the threshold. This indicates that while the media effectively improves understanding, additional pedagogical strategies—such as explicit teacher guidance, peer collaboration, or formative assessment—may be needed to help students fully master complex scientific content. This aligns with Hwang et al. (2023), who emphasize the importance of integrating scaffolding and feedback mechanisms into digital learning environments to optimize outcomes.

To visualize the comparative progress, Figure 2 presents the normalized gain (N-Gain) for both science literacy and environmental awareness in the treatment and control groups.

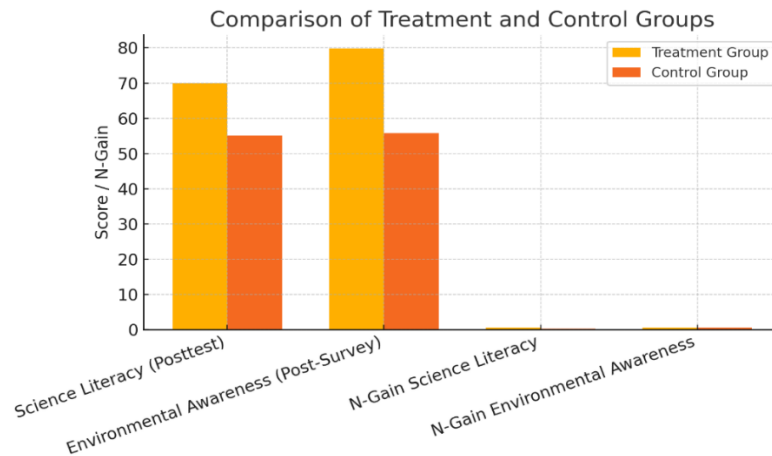


Figure 2. Normalized Gain (N-Gain) for Both Science Literacy and Environmental Awareness

Table 7. One Sample Test of Variables at Beta Test

Variable	Test Value	Mean	p value	Cohen's d	Effect Size
Student' Science Literacy	70	70.00	1.000	0.000	
Students' Awareness	70	79.76	0.000	2.373	

As presented in Table 7, the mean score for students' science literacy in the treatment group ( $M = 70.00$ ) met the minimum competency threshold (KKTP) but did not show a statistically significant difference ( $p = 1.000$ ,  $d = 0.000$ ). This indicates that while students reached the expected performance level, their learning progress plateaued once they approached the benchmark.

Conversely, environmental awareness demonstrated a statistically significant improvement ( $p < 0.001$ ) with a large effect size ( $d = 2.373$ ), reflecting the strong influence of narrative and emotional engagement embedded within the digital storytelling media. These contrasting outcomes suggest that cognitive understanding and affective awareness may progress differently within narrative-based instruction.

### Discussion

The results of this study affirm the potential of scientific-based digital storytelling as an effective pedagogical approach for enhancing science literacy and environmental awareness among junior high school students. By integrating narrative, local environmental context, and real-world data, the media provided students with meaningful learning experiences that traditional instruction often fails to achieve (Adnan et al., 2021; OECD, 2023a). The consistent improvements observed across both phases of the study suggest that when digital storytelling is grounded in scientific content and aligned with curriculum goals, it can promote both cognitive engagement and environmental responsibility.

In the area of science literacy, students who engaged with the storytelling media demonstrated noticeable development in interpreting environmental data, recognizing relationships between variables, and conveying information through visual formats. These are key competencies emphasized in the PISA science literacy framework (OECD, 2023b). The ability of students to engage in such higher-order thinking through narrative-based media supports the argument made by Yang and Wu (2012) and Göksün and Gürsoy

(2022), who found that digital storytelling can improve both conceptual understanding and student motivation. The narrative format appears to reduce cognitive overload by embedding abstract scientific concepts within familiar storylines, making them more accessible and memorable.

However, the findings also suggest that digital storytelling alone may not be sufficient to ensure full mastery of scientific competencies. While students showed progress, many still struggled with scientific vocabulary and data interpretation when working independently. This challenge echoes the work of Robin (2008) and Hwang et al. (2023), who emphasize the need for teacher mediation and scaffolding in technology-rich learning environments. Their research underlines that digital media should be embedded within a broader pedagogical framework that includes explicit instruction, collaborative discussion, and formative feedback.

The use of storytelling also proved effective in promoting environmental awareness. The narrative of Kancil, which addressed local environmental problems such as deforestation, pollution, and climate change, encouraged students to engage emotionally and critically with ecological issues. This combination of emotional narrative and factual data mirrors the model described by Andriopoulou et al. (2022), who argue that digital storytelling creates space for empathy and reflection, key components of sustainability literacy. Similarly, Tramonti et al. (2024) highlight the role of storytelling in activating students' sense of agency by helping them see environmental problems as relevant to their own lives and communities.

Student and teacher feedback further reinforced the practicality of the media. Its mobile accessibility and intuitive design contributed to classroom engagement, while the AI-generated illustrations and interactive elements helped sustain student interest throughout the learning process. This aligns with Smeda et al. (2014), who describe digital storytelling as a constructivist tool that promotes student-centered learning through interaction and personalization. Similarly, Nasrullah, Arsyad, and Alimuddin (2025) emphasized that project-based manipulative and virtual learning environments enhance students' growth mindset by expanding their opportunity to learn. This finding reinforces the present study's argument that digital storytelling functions not only as a narrative and cognitive scaffold, but also as an affective catalyst for self-directed and meaningful learning. Teachers in the study noted that students were more focused and participatory during storytelling sessions compared to conventional lessons.

Nonetheless, the study also revealed the importance of explicitly supporting language development within science education. Students often encountered difficulties with unfamiliar terms and abstract representations. This is consistent with observations from Bilen et al. (2019), who emphasized that students need targeted support in scientific language to effectively navigate and construct meaning from data-rich media. Robin (2008) similarly cautioned that while digital storytelling supports engagement, it must be complemented with structured guidance to fully develop students' scientific communication skills.

Taken together, these findings support the view that digital storytelling—particularly when informed by real-world data and embedded within a sound instructional design—has strong potential to enhance multiliteracies in science education. As the New London Group (1996) suggests, effective literacy instruction today must integrate multiple modes of meaning-making, including visual, textual, and digital. The approach used in this study positioned students not only as readers of scientific content but as interpreters and communicators of science through a narrative lens. In doing so, it supports the development of both critical literacy and environmental literacy, enabling students to understand global ecological issues through local, personal, and culturally relevant stories (Tilbury, 1995; Guerrero & Sjöström, 2024).

The results of this study support Indonesia's *Kurikulum Merdeka* agenda, which promotes contextual and project-based learning as pathways to develop environmental literacy and critical thinking (Kemdikbud, 2022). The observed gains in students' science literacy and awareness demonstrate how digital storytelling can operationalize the *Profil Pelajar Pancasila* dimensions of critical reasoning and ecological awareness in practical classroom contexts.

## CONCLUSION

This study demonstrates that scientific-based digital storytelling is a promising instructional approach for enhancing junior high school students' science literacy and environmental awareness. The integration of culturally contextualized narratives, real-world data, and interactive digital formats effectively supports students' engagement and conceptual understanding. Both the alpha and beta testing phases revealed significant learning gains, particularly in interpreting data and recognizing environmental issues—core components of 21st-century scientific literacy.

However, the findings also highlight that digital media alone may not be sufficient to achieve full mastery of scientific competencies. Although students' scores improved, they did not statistically surpass the minimum passing criteria, suggesting the need for teacher scaffolding, formative assessment, and follow-up tasks to reinforce learning. This implies that digital storytelling should be embedded within a broader pedagogical strategy that includes discussion, reflection, and active inquiry.

Ultimately, this research affirms the pedagogical value of multimodal, narrative-based learning experiences in science education. It contributes to the growing body of work that views literacy not merely as decoding information, but as a critical, contextualized, and action-oriented practice. Digital storytelling offers a meaningful pathway to foster multiliteracies, connect students with real-world challenges, and promote environmental responsibility—making it highly relevant for interdisciplinary literacy educators.

## CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this article.

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