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Enhancing Scientific Literacy through Ethnoscience Based Pop-Up Books: A Pre-Experimental Study in Elementary Education

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Abstrak

Literasi sains merupakan kompetensi fundamental bagi peserta didik abad ke-21, namun Indonesia berada di peringkat bawah dalam asesmen internasional seperti PISA. Penelitian ini bertujuan untuk mengetahui pengaruh penggunaan pop-up book berbasis etnosains terhadap literasi sains siswa kelas IV SDN 37 Kabupaten Sorong, Papua Barat Daya. Dengan menggunakan desain *one-group pretest-posttest* dan total sampling (n = 8), penelitian ini memanfaatkan pop-up book yang mengintegrasikan pengetahuan etnosains lokal Papua, khususnya tanaman obat tradisional (*Piper betle*, *Curcuma longa*, dan *Zingiber officinale* var. *rubrum*), ke dalam konten sains sesuai kurikulum nasional. Data dikumpulkan melalui tes literasi sains 20 butir pilihan ganda berdasarkan tiga indikator PISA: (1) menjelaskan fenomena secara ilmiah, (2) mengevaluasi dan merancang penyelidikan ilmiah, dan (3) menginterpretasi data dan bukti. Validitas instrumen dikonfirmasi oleh dua ahli pendidikan sains dan normalitas data diverifikasi menggunakan uji Shapiro-Wilk. Hasil menunjukkan peningkatan rerata skor dari 47,50 (pretest) menjadi 78,13 (posttest) dengan rerata N-gain sebesar 0,58. Uji t sampel berpasangan mengonfirmasi signifikansi statistik (t = 10,32; df = 7; p < 0,001). Temuan ini mengindikasikan bahwa pop-up book berbasis etnosains menunjukkan peningkatan literasi sains siswa pada kategori sedang, dan menawarkan strategi pedagogis non-digital bagi sekolah dasar terpencil di Indonesia bagian timur.

Kata kunci: literasi sains; etnosains; *pop-up book*; pendidikan dasar; papua

Abstract

Scientific literacy is a foundational competency for 21st-century learners, yet Indonesia consistently ranks among the lowest performers in international assessments such as PISA. This study aimed to examine the effect of ethnoscience-based pop-up books on the scientific literacy of Grade 4 students at SDN 37, Kabupaten Sorong, Southwest Papua. Employing a one-group pretest-posttest design with total sampling (n = 8), the study used an existing pop-up book integrating local Papuan ethnoscience knowledge, specifically traditional medicinal plants (Piper betle, Curcuma longa, and Zingiber officinale var. rubrum), into science content aligned with the national curriculum. Data were collected through a 20-item multiple-choice scientific literacy test based on three PISA indicators: (1) explaining phenomena scientifically, (2) evaluating and designing scientific inquiry, and (3) interpreting data and evidence. Instrument validity was confirmed by two science education experts, and data normality was verified using the Shapiro-Wilk test. Results demonstrated an increase in mean scores from 47.50 (pretest) to 78.13 (posttest), yielding an average N-gain of 0.58 (moderate category). A paired-sample t-test confirmed statistical significance (t = 10.32, df = 7, p < 0.001). These findings indicate that ethnoscience-based pop-up books demonstrated a moderate improvement in students' scientific literacy by bridging local cultural knowledge with formal scientific concepts, offering a non-digital pedagogical strategy for remote elementary schools in eastern Indonesia.

Keywords: *scientific literacy; ethnoscience; pop-up book; elementary education; papua*

INTRODUCTION

Scientific literacy is an essential competency that students must master to face the challenges of the 21st century. This competency encompasses the ability to understand, apply, and make science-based decisions in everyday life (Rahma et al., 2026; Putra & Wahyuni, 2025). More broadly, scientific literacy involves the capacity to recognize, understand, evaluate, and apply scientific knowledge to explain natural phenomena and solve complex problems in society (Sjostrom, 2025; Kahn et al., 2025). According to the OECD (2023) in the PISA program, scientific literacy is one of the primary indicators of a country's educational quality, measuring students' ability to use scientific knowledge to explain phenomena and make evidence-based decisions. Therefore, the development of scientific literacy should begin at the elementary education level through contextual, meaningful, and socioculturally responsive learning (Zhang et al., 2023; Mede et al., 2025; Turiman et al., 2012).

However, Indonesian students' scientific literacy achievements remain low by international standards. Based on the PISA 2022 results, Indonesia obtained an average scientific literacy score of 383 points, far below the OECD average of 485 points (OECD, 2023). This low achievement is influenced by various factors, including the limited availability of contextual learning media, the lack of integration of local culture in science curricula, and the disparity in educational quality between urban and rural areas (Yusmar & Fadilah, 2023; Sari et al., 2025). This situation is particularly critical in remote regions such as Kabupaten Sorong, West Papua, where most elementary schools lack adequate and culturally relevant science learning media (Sari et al., 2025; Hutauruk et al., 2026).

Ethnoscience as a learning approach that integrates local cultural knowledge with modern scientific concepts has received increasing attention in the global science education literature (Brandt & Chernoff, 2015; Sudarmin et al., 2019). This approach has the potential to bridge the gap between traditional community knowledge and formal school science, making learning more relevant and meaningful for students (Aikenhead & Jegede, 1999; Turiman et al., 2012). Papuan communities possess extraordinary local knowledge, including knowledge of traditional medicinal plants passed down through generations. However, this wealth of knowledge has not been optimally utilized as a science learning resource capable of strengthening students' scientific literacy (Hutauruk et al., 2026; Putra & Wahyuni, 2025).

Various studies have examined the use of innovative learning media to improve scientific literacy. Digital-based media has proven effective but remains difficult to access in remote schools (Kusumawati & Prastiwi, 2025). On the other hand, pop-up books as concrete and interactive three-dimensional media have been shown to enhance students' conceptual understanding and learning motivation without reliance on digital infrastructure (Ibrahim et al., 2025; Akina et al., 2023; Mauidah et al., 2025). Pop-up books also allow for the integration of ethnoscience content in visual and narrative formats. Although numerous studies have examined ethnoscience-based learning, the use of Papua local culture-based pop-up book media to enhance elementary school students' scientific literacy remains underexplored.

This research gap forms the basis of this study's originality and novelty. Previous studies on ethnoscience-based learning have generally focused on: (1) digital media formats that are inaccessible in remote areas (Kusumawati & Prastiwi, 2025); (2) urban school contexts that do not reflect the socio-cultural reality of eastern Indonesian students; and (3) general science outcomes without specifically measuring PISA-based scientific literacy indicators. None of these studies has empirically tested the effectiveness of pop-up books integrating local Papuan medicinal plant knowledge as a non-digital ethnoscience medium for scientific literacy in remote elementary settings. This study addresses those gaps by employing a pre-experimental design with real field data from SDN 37, Kabupaten Sorong, aiming to determine the effect of ethnoscience-based pop-up book usage on the scientific literacy of Grade 4 students.

METHOD

This study employed a pre-experimental research design with a one-group pretest-posttest design (Anisa et al., 2026; Creswell & Creswell, 2018). In this design, a single group of subjects received a pretest prior to the intervention (O_1), followed by treatment in the form of learning using ethnoscience-based pop-up books (X), and concluded with a posttest (O_2). This design was selected because field conditions, characterized by a very limited number of subjects did not permit the inclusion of a control group. The research design pattern is as follows:

$$O_1 \quad X \quad O_2$$

Note: O_1 = Pretest; X = Treatment (ethnoscience pop-up book learning); O_2 = Posttest

The population of this study comprised all Grade 4 students at SDN 37, Kabupaten Sorong, totaling 8 students. Given the very small population size, a total sampling technique was employed, in which all population members served as research subjects (Arikunto, 2010; Cohen et al., 2018). Such conditions commonly occur in remote elementary schools in West Papua, where educational access and learning resources remain limited, resulting in class sizes consisting of only a small number of students due to low population density.

The medium used was an existing, ready-to-use ethnoscience-based pop-up book. This pop-up book contained local Papuan ethnoscience content specifically, indigenous community knowledge of traditional medicinal plants explicitly connected to formal science concepts in the national curriculum. The three plants featured as focal topics are presented in Table 1.

Table 1. Papuan ethnoscience medicinal plants featured in the pop-up book and associated science concepts

Medicinal Plant	Scientific Name	Papuan Local Knowledge	Formal Science Concepts
Betel Leaf	*Piper betle*	Used as antiseptic and traditional dental care	Leaf structure, photosynthesis, plant active compounds
Turmeric	*Curcuma longa*	Used as anti-inflammatory agent and natural dye	Plant organs (rhizome), plant pigments, adaptation
Red Ginger	*Zingiber officinale var. rubrum*	Used to warm the body and boost immunity	Vegetative reproduction, plant parts, plant benefits

Source: Adapted from Hutauruk et al. (2026) and Putra & Wahyuni (2025)

The learning procedure was implemented in three main phases. First, the Ethnoscience Exploration Phase (Session 1): students were invited to share their experiences with medicinal plants known in their community, and the teacher introduced the pop-up book and its use. Second, the Science Connection Phase (Sessions 2–3): students studied the pop-up book content systematically, linking ethnoscience knowledge with scientific concepts through group discussion and direct plant specimen observation. Third, the Reflection and Confirmation Phase (Session 4): students presented their understanding and the teacher provided concept reinforcement. All activities followed the principles of ethnoscience learning (Sudarmin et al., 2019) and contextual teaching (Aikenhead & Jegede, 1999).

Data were collected through a written scientific literacy test administered before (pretest) and after (posttest) the intervention. The test instrument comprised 20 multiple-choice items with four answer options, developed in reference to the three scientific literacy competencies from PISA 2022 (OECD, 2023). The distribution of items by indicator and cognitive level is presented in Table 2.

Table 2. Distribution of scientific literacy test

Scientific Literacy Indicator (PISA)	No. of Items	Cognitive Level	Percentage (%)
1. Explaining phenomena scientifically	8	C1, C2, C3	40
2. Evaluating and designing scientific inquiry	6	C3, C4	30
3. Interpreting data and evidence scientifically	6	C4, C5	30
Total	**20**	**C1–C5**	**100**

Source: Adapted from OECD (2023)

Prior to use, the instrument was validated by two science education expert validators and its readability was tested with three Grade 4 students outside the research subjects. All test items were declared valid and suitable for use based on the expert validation results.

Data analysis was conducted quantitatively in two stages. First, improvements in scientific literacy were analyzed using the Normalized Gain (N-gain) formula from Hake (1998) as follows:

$$\text{N-gain} = \frac{(\text{Posttest score} - \text{Pretest score})}{(\text{Maximum Score} - \textit{Pretest Score})}$$

Interpretation of N-gain values followed Hake's (1998) criteria: high if $g > 0.70$; moderate if $0.30 \leq g \leq 0.70$; and low if $g < 0.30$. Second, to test the significance of differences between pretest and posttest scores, a paired-sample t-test was conducted at a significance level of $\alpha = 0.05$ using SPSS. Prior to the t-test, data normality was verified using the Shapiro-Wilk test, which is recommended for small samples ($n < 30$) (Field, 2018; Pallant, 2020). The hypotheses tested were: H_0 (there is no significant difference between pretest and posttest scores) and H_1 (there is a significant difference between pretest and posttest scores).

RESULTS AND DISCUSSION

A normality test was conducted as a prerequisite for parametric analysis using the Shapiro-Wilk test, given that the sample size was less than 30 (Field, 2018). The normality test results are presented in Table 3.

Table 3. Shapiro-Wilk normality test results

Data	N	Statistic (W)	df	Sig. (p)
Pretest	8	0.941	8	0.621
Posttest	8	0.927	8	0.490

Source: SPSS Output, 2026

The Shapiro-Wilk significance values for both the pretest data ($p = 0.621$) and posttest data ($p = 0.490$) exceeded 0.05, confirming that the normality assumption was satisfied and justifying the use of parametric t-testing (Pallant, 2020).

The pretest scores, posttest scores, gain scores, and N-gain values for each student are presented in Table 4

Table 4. Students' pretest, posttest, and N-gain scores for scientific literacy

No.	Student	Pretest	Posttest	Gain	N-gain	Category
1	S-1	45	75	30	0.55	Moderate
2	S-2	50	80	30	0.60	Moderate
3	S-3	40	70	30	0.50	Moderate
4	S-4	55	85	30	0.67	Moderate
5	S-5	45	75	30	0.55	Moderate
6	S-6	50	80	30	0.60	Moderate
7	S-7	40	75	35	0.58	Moderate
8	S-8	55	85	30	0.67	Moderate
	Mean	**47.50**	**78.13**	**30.63**	**0.58**	**Moderate**
	Min.	**40.00**	**70.00**	**30.00**	**0.50**	**Moderate**
	Max.	**55.00**	**85.00**	**35.00**	**0.67**	**Moderate**

Source: Primary data, processed 2026

All eight students demonstrated an increase in scores from pretest to posttest. The mean pretest score of 47.50 increased to 78.13 on the posttest, with a mean gain of 30.63 points. Individual N-gain values ranged from 0.50 to 0.67, and all students were categorized under moderate N-gain. No student fell into either the low or high category, indicating consistency of the treatment effect across all research subjects. Notably, variation in N-gain values across scientific literacy indicators warrants further pedagogical interpretation, particularly regarding the relatively lower performance on inquiry-based reasoning skills, as elaborated subsequently.

To provide a more detailed picture of improvement patterns, an analysis of scores per scientific literacy indicator was conducted. Results are presented in Table 5.

Table 5. Mean scores and N-gain per scientific literacy indicator

Scientific Literacy Indicator	Mean Pretest	Mean Posttest	N-gain	Category
Explaining scientific phenomena	48.75	80.00	0.61	Moderate
Designing scientific inquiry	46.88	76.04	0.55	Moderate
Interpreting data and evidence	46.88	77.08	0.57	Moderate
Overall Mean	**47.50**	**78.13**	**0.58**	**Moderate**

Source: Primary data, processed 2026

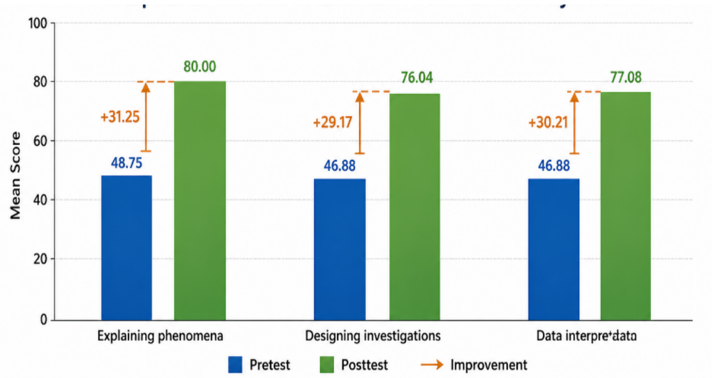

Figure 1. Comparison of mean pretest and posttest score by indicator

Table 5 and Figure 1 shows that the greatest improvement occurred in the indicator of explaining phenomena scientifically (N-gain = 0.61; gain = 31.25 points), followed by interpreting data and evidence (N-gain = 0.57; gain = 30.21 points), and designing scientific inquiry (N-gain = 0.55; gain = 29.17 points). This pattern suggests that ethnoscience-based pop-up books are most effective in supporting conceptual understanding, while higher-order thinking skills require further reinforcement.

A paired-sample t-test was conducted to examine the significance of the improvement in scientific literacy. The complete t-test results are presented in Table 6.

Table 6. Paired-sample t-test results for pretest and posttest scientific literacy scores

Variable	Mean	Std. Dev.	t-value	df	Sig.
Pretest → Posttest	−30.63	8.39	−10.32	**7**	0.000

Source: SPSS Output, 2026

The t-test results yielded a t-value of −10.32 with df = 7 and a significance value of 0.000 ($p < 0.001$). Since the p-value was well below the significance level of $\alpha = 0.05$, H_0 was rejected and H_1 was accepted, indicating a significant difference between students' scientific literacy scores before and after the use of ethnoscience-based pop-up books.

The findings of this study demonstrate that ethnoscience-based pop-up books exerted a positive and significant effect on the scientific literacy of Grade 4 students (mean N-gain = 0.58; t = −10.32; $p < 0.001$). These results are consistent with and reinforce the findings of several previous studies. Akina et al. (2023) found that pop-up book media significantly improved mathematics and science learning outcomes in elementary students. Mauidah et al. (2025) similarly reported that pop-up books enhanced students' visualization abilities and conceptual understanding of science. Ibrahim et al. (2025) demonstrated that augmented reality-based pop-up books improved students' understanding of ecosystem concepts, confirming the potential of the pop-up format as an effective science medium.

The improvement in scientific literacy can be explained through several pedagogical mechanisms. First, from an ethnoscience perspective, the context of traditional Papuan medicinal plants functioned as a "cognitive bridge" that helped students connect their pre-existing informal knowledge with formal scientific concepts (Aikenhead & Jegede, 1999). Students in Kabupaten Sorong already possessed prior knowledge of betel leaf, turmeric, and red ginger in their everyday lives. This prior knowledge served as a cognitive schema facilitating the assimilation of new concepts about the structure and function of plant organs (Novak, 2010). Putra & Wahyuni (2025) affirm that integrating local wisdom into science learning consistently enhances student engagement and understanding because the material feels relevant to their lives.

Second, from a learning media perspective, the three-dimensional characteristics of pop-up books provide a concrete and multisensory learning experience, consistent with the cognitive developmental stage of Grade 4 elementary students who are in the concrete operational phase according to Piaget's theory (Mauidah et al., 2025). The physical and sensory engagement of opening each pop-up page supports the formation of stronger mental representations. This is consistent with dual-coding theory, which posits that information processed both verbally and visually simultaneously is more readily understood and retained (Mayer, 2009). These findings also align with the multimedia learning principle that learning is more effective when words and images are presented together rather than words alone (Mayer, 2009).

Third, the narrative-rich ethnoscience context and local cultural values embedded in the pop-up book contributed to an increase in students' intrinsic motivation to learn science (Kahn et al., 2025; Sjostrom, 2025). This aligns with the principles of culturally responsive teaching, which emphasizes the importance of responding to students' cultural backgrounds in the learning process to enhance engagement and academic achievement (Gay, 2018). In the context of remote elementary schools in Papua, which have historically lacked contextual learning media the ethnoscience pop-up book provided fresh and meaningful learning stimulation (Sari et al., 2025; Hutauruk et al., 2026).

The indicator of designing scientific inquiry obtained the lowest N-gain (0.55), suggesting that higher-order thinking skills (HOTS) such as designing and evaluating scientific investigations cannot be optimally developed through pop-up book media alone. A closer examination reveals several reasons why students encountered difficulties with this indicator. Designing scientific inquiry requires students to formulate hypotheses, plan procedures, and evaluate evidence, which are cognitive processes that belong to the upper levels of Bloom's taxonomy (C4 and C5) and demand abstract reasoning beyond the concrete operational stage typical of Grade 4 students (Piaget, as cited in Mauidah et al., 2025).

Among the HOTS dimensions, the ability to evaluate and construct scientific procedures was particularly weak, as the pop-up book's visual-narrative format primarily supports knowledge reception rather than active knowledge construction. This pattern reflects an inherent characteristic of visual media: while pop-up books are highly effective for building conceptual understanding through the dual-coding of verbal and pictorial information (Mayer, 2009), they do not inherently scaffold the procedural reasoning required for inquiry design.

This finding is consistent with Zhang et al. (2023) and Manassero-Mas and Vazquez-Alonso (2022), who assert that high-level scientific competencies require active inquiry experiences. Therefore, ethnoscience pop-up books should ideally be combined with hands-on activities such as plant observation, simple experiments, and evidence-based discussion to develop inquiry-related HOTS more effectively. Turiman et al. (2012) also emphasize that 21st-century science process skills develop most effectively through the combination of learning media and direct inquiry activities.

Contextually, these findings carry important practical implications for science education in remote eastern Indonesian regions. Ethnoscience-based pop-up books offer a non-digital pedagogical solution that can be implemented in schools with limited technological infrastructure, while simultaneously honoring and integrating the richness of Papuan local culture into formal learning in alignment with the spirit of the Merdeka Curriculum (Wijaya et al., 2025). Several limitations must be acknowledged: (1) the very small sample size (n = 8) limits statistical power and generalizability; (2) the pre-experimental design without a control group cannot fully isolate the effect of the pop-up book from internal validity threats such as testing effects, maturation, and history (Campbell & Stanley, 1963, as cited in Creswell & Creswell, 2018); and (3) the short duration of the study precluded examination of long-term retention. Nevertheless, this study provides important preliminary evidence as a foundation for more comprehensive future research.

CONCLUSION

This study concludes that ethnoscience-based pop-up books exerted a positive and significant effect on the scientific literacy of Grade 4 students at SDN 37, Kabupaten Sorong. The improvement in mean scores from 47.50 (pretest) to 78.13 (posttest) yielded a mean N-gain of 0.58 (moderate category), and the paired-sample t-test confirmed statistical significance ($t = -10.32$; $df = 7$; $p < 0.001$). The greatest improvement was observed in the indicator of explaining scientific phenomena (N-gain = 0.61), while the indicator of designing scientific inquiry still requires further reinforcement (N-gain = 0.55). These results provide convincing preliminary evidence that ethnoscience-based pop-up books demonstrated a moderate improvement in students' scientific literacy by building a cognitive bridge between Papuan local cultural knowledge and formal scientific concepts.

Ethnoscience-based pop-up books are recommended as a contextual, non-digital science learning medium for remote elementary schools in Papua and eastern Indonesia with limited digital infrastructure. Future research should (1) replicate the study with larger samples using a quasi-experimental design; (2) combine ethnoscience pop-up books with direct inquiry activities; and (3) develop pop-up books incorporating other forms of Papuan ethnoscience knowledge.

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