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Effect of the Pancaniti Learning Model Assisted by Flashcard Media and a Simple Biogas Project on the Science Literacy of Elementary School Students

Leni Nurhafidah*, Afridha Laily Alindra, Dania Widia Cahyani, Yuhaniz Aqila, Nurlaila Ramadhan, Mochamad Ilham Abdillah, Caroline Glorya Manurung
Universitas Pendidikan Indonesia, Indonesia
**Corresponding author*: leni.nur12@upi.edu

Abstract: Science literacy among Indonesian elementary school students remains below international benchmarks, while locally grounded instructional approaches that integrate sustainability education are still limited. This study investigated the effect of the Pancaniti learning model, a five-stage pedagogical framework based on Sundanese values, combined with flashcard media and a simple biogas project, on fifth-grade students' science literacy. A one-group pre-test–post-test quasi-experimental design was conducted with 32 Grade 5 students at SDN Purwamekar selected through purposive sampling. Science literacy was measured using three PISA-aligned indicators: identifying scientific problems, explaining scientific phenomena, and using scientific evidence. Data analysis employed the Wilcoxon Signed-Rank Test due to non-normal post-test data. Results showed a significant improvement in science literacy, with mean scores increasing from 6.44 to 8.44 ($Z = -4.112$, $p < .001$) and a large effect size ($r = 0.727$). The overall N-Gain was 0.58 (moderate), with the highest gain in using scientific evidence (0.72; high). These findings indicate that the Pancaniti model effectively enhances elementary students' science literacy.

Keywords: biogas project; Education for Sustainable Development; elementary science literacy; flashcard; N-Gain; Pancaniti model; PISA science indicators

Abstrak: *Literasi sains siswa sekolah dasar di Indonesia masih berada di bawah standar internasional, sementara pembelajaran berbasis kearifan lokal yang terintegrasi dengan pendidikan keberlanjutan masih terbatas. Penelitian ini bertujuan menganalisis pengaruh model pembelajaran Pancaniti yang dipadukan dengan media flashcard dan proyek pembuatan biogas sederhana terhadap literasi sains siswa kelas V SD. Penelitian menggunakan desain kuasi eksperimen one-group pre-test–post-test dengan melibatkan 32 siswa SDN Purwamekar yang dipilih secara purposive sampling. Literasi sains diukur berdasarkan tiga indikator PISA, yaitu mengidentifikasi masalah ilmiah, menjelaskan fenomena ilmiah, dan menggunakan bukti ilmiah. Hasil uji Wilcoxon Signed-Rank menunjukkan adanya peningkatan yang signifikan antara skor pre-test dan post-test ($Z = -4{,}112$; $p < 0{,}001$). Rata-rata skor meningkat dari 6,44 menjadi 8,44 dengan ukuran efek besar ($r = 0{,}727$). Nilai N-Gain keseluruhan sebesar 0,58 (kategori sedang), sedangkan peningkatan tertinggi terdapat pada indikator penggunaan bukti ilmiah (N-Gain = 0,72; kategori tinggi). Temuan ini menunjukkan bahwa model Pancaniti efektif dalam meningkatkan literasi sains siswa sekolah dasar.*

Kata Kunci: *iterasi sains, model Pancaniti, flashcard, proyek biogas, sekolah dasar, N-Gain*

INTRODUCTION

Science literacy broadly defined as the capacity to engage with science-related issues through evidence-based reasoning, conceptual understanding, and critical evaluation of natural phenomena is a core outcome of contemporary science education (OECD, 2022). The PISA 2022 Science Framework operationalises science literacy through three competency domains: identifying scientific questions, explaining phenomena scientifically, and interpreting data and evidence scientifically (OECD, 2022). Indonesia's persistent underperformance on PISA science assessments consistently ranking in the lower quartile of participating nations highlights the systemic gap between curriculum intentions and classroom outcomes, particularly at the elementary level where foundational science dispositions are formed (Holbrook & Rannikmae, 2009).

The urgency of addressing science literacy at the elementary level is compounded by the global imperative of sustainability education. The United Nations Sustainable Development Goals (SDG 4.7) explicitly mandate that education systems promote the knowledge and skills required to advance sustainable development, including through environmental awareness and scientific reasoning (UNESCO, 2017). In Indonesia, the national curriculum for elementary science (IPAS) emphasises renewable energy as a thematic context precisely suited to cultivating both conceptual understanding and environmental agency. Against this backdrop, the development of instructional approaches that simultaneously build science literacy and sustainability awareness among young learners constitutes a research and pedagogical priority.

Despite the documented low science literacy of Indonesian elementary students characterised by rote memorisation, teacher-centredness, and limited exposure to inquiry-based activities (Salame et al., 2025) instructional interventions that integrate local cultural wisdom with science inquiry remain underrepresented in the published literature. Most available studies either examine generic inquiry or project-based approaches without a cultural grounding (Krajcik & Shin, 2014), or document Islamic-values integration without addressing sustainability competencies. The Pancaniti model, a five-stage learning framework derived from Sundanese philosophical values developed in Purwakarta Regency (Dinas Pendidikan Purwakarta, 2020), offers a distinctive pedagogical architecture that bridges local wisdom, scientific process skills, and Education for Sustainable Development (ESD). However, its empirical effect on PISA-aligned science literacy outcomes particularly when combined with visual media and hands-on project work has received limited systematic investigation.

Two specific component gaps motivate this study. First, the pedagogical synergy between the Pancaniti stages and the PISA science literacy competency domains has not been formally mapped or empirically tested. Second, the additive effect of incorporating concrete experiential artefacts (biogas construction) and visual stimulus materials (flashcards) within a locally grounded model on indicator-level literacy gains has not been reported.

The Pancaniti model's five stages consist of niti harti (observation), niti surti (conceptual planning), niti bukti (evidential investigation), niti bakti (critical evaluation and reflection), and niti sajati (communicating findings) align structurally with both Kolb's (1984) Experiential Learning Cycle and the scientific inquiry process described in the Next Generation Science Standards framework (Krajcik & Shin, 2014). Each stage scaffolds a distinct cognitive and affective process, creating a coherent pedagogical arc from concrete experience to abstract conceptualisation.

The integration of flashcard media addresses the visual processing demands of abstract science concepts. Pan and Rickard's (2018) meta-analysis of retrieval practice confirmed that active-recall strategies, operationalised through flashcard use, significantly improve long-term retention and conceptual transfer. Flashcards are particularly suited to the niti surti stage, where students engage in conceptual planning and vocabulary consolidation prior to investigation (Wati & Mahendra, 2025).

The simple biogas construction project functions as both a scientific investigation and a sustainability learning activity. It provides authentic contexts in which students must identify a problem (renewable energy), design and execute an investigation (niti bukti), and evaluate outcomes against real-world criteria (niti bakti), directly activating all three PISA science literacy competency domains (OECD, 2022). This alignment with ESD principles connecting classroom learning to environmental agency positions the intervention as a contribution to the broader education for sustainability literature (Alindra et al., 2025; UNESCO, 2017).

This study pursued three objectives: (1) to determine whether the Pancaniti-Flashcard-Biogas intervention produced a statistically significant and practically meaningful improvement in science literacy scores among fifth-grade students; (2) to characterise the differential effect of the intervention across the three PISA science literacy indicators; and (3) to contribute to the knowledge base on culturally grounded, sustainability-oriented instructional models for elementary science education.

The study makes three specific contributions to the literature. First, it provides the first systematic, quantitatively evaluated mapping of the Pancaniti model stages onto PISA science literacy indicators. Second, it introduces a tripartite instructional intervention culturally grounded model, visual media, hands-on sustainability project and documents its differential effects at the indicator level, rather than relying solely on aggregate scores. Third, it calculates and reports effect size (rank-biserial correlation, r = 0.727), which is absent from prior Pancaniti studies, enabling cross-study comparison. Together, these contributions extend the evidence base for ESD-aligned, culturally responsive science instruction at the elementary level in Indonesia and comparable contexts.

METHOD

Research Design

A quantitative quasi-experimental design with a one-group pre-test–post-test structure (O_1 X O_2) was employed (Sugiyono, 2017). This design was selected because the research context a single participating school with intact class groupings precluded random assignment to experimental and control conditions.

Participants

The accessible population comprised all Grade 5 students at SDN Purwamekar. A purposive sample of n = 32 students from one Grade 5 class was selected on the basis of: (a) teacher-confirmed enrolment in the IPAS renewable energy unit, (b) parent/guardian written informed consent, and (c) student verbal assent. No student was excluded for any other criterion. Participant age ranged from 10 to 11 years (M = 10.6 years). All participant identities are protected; the school is referred to by its administrative code only.

Intervention Description

The intervention comprised three integrated components delivered in sequence over each instructional session.

Component 1: Pancaniti learning model. The five-stage Pancaniti framework (Rachman et al., 2022) was applied as follows within the renewable energy unit: (1) Niti harti: students observed renewable energy sources present in the local environment, including organic waste in school canteen areas. (2) Niti surti: students used flashcards to review key concepts (biogas, anaerobic decomposition, renewable vs non-renewable energy) and planned their investigation. (3) Niti bukti: students constructed and tested a simple biogas model using plastic bottles, organic kitchen waste, water, and yeast, following a guided inquiry protocol. (4) Niti bakti: students evaluated project outcomes, recorded observations, and engaged in structured peer discussion. (5) Niti sajati: student groups presented their findings and reflections to the class.

Component 2: Flashcard media. A set of [INSERT: number] full-colour science flashcards was developed by the research team, covering key vocabulary, concepts, and visual representations of biogas production, the carbon cycle, and energy conversion. Each card carried a term on one side and a visual definition on the reverse, following Pan and Rickard's (2018) active-recall design principles. Flashcards were used during the niti surti stage and were also available during niti bukti as a reference resource.

Component 3: Simple biogas project. Students assembled a sealed anaerobic fermentation apparatus using a 1.5-litre plastic bottle, organic kitchen waste (vegetable peels), water, and a small quantity of yeast as inoculant. The apparatus was monitored over two consecutive class sessions; students recorded gas production observations and used these data as the primary evidential source for their written conclusions.

Instruments

Science literacy was measured using a researcher-developed achievement test aligned with three PISA science literacy indicators (OECD, 2022; Winata et al., 2018): (1) identifying scientific problems (4-point maximum score), (2) explaining scientific phenomena (3-point maximum), and (3) using scientific evidence (3-point maximum), yielding a maximum composite score of 10.

Content validity was established through expert review by two science education specialists, yielding an Aiken's V index of $V = 0.82$ for each item. Internal consistency was assessed using Cronbach's α: pre-administration pilot data yielded $\alpha = 0.73$, and full-administration internal consistency was $\alpha = 0{,}76$ (Arikunto, 2013).

Data Analysis

Descriptive statistics (mean, standard deviation, percentage) were computed for pre-test and post-test scores, both overall and per indicator. Normality was assessed using both the Shapiro–Wilk test (preferred for $n \leq 50$; Razali & Wah, 2011) and the Kolmogorov–Smirnov test. Because post-test data violated the normality assumption ($\rho < .001$), the Wilcoxon Signed-Rank Test was selected as the primary inferential test. Effect size was estimated using the rank-biserial correlation coefficient, Benchmarks from Cohen (1988) were applied: $r \geq 0.50$ = large effect. Normalised Gain (N-Gain) was calculated using the formula of Hake (1998): N-Gain = (post-test − pre-test) / (maximum − pre-test), interpreted as: ≥ 0.70 = high; 0.30–0.70 = moderate; < 0.30 = low. All analyses were performed using SPSS version 26.

Ethical Considerations

Parental/guardian written informed consent and student verbal assent were obtained prior to any data collection. The school principal provided institutional permission. No student data are identified by name in this manuscript; all participants are referred to by numerical codes.

Results

Descriptive Statistics

Table 1 presents the descriptive statistics for the pre-test and post-test science literacy scores. The mean score increased by 2.00 points (20 percentage-point gain), from 6.44 (64.4% of maximum; SD = 1.72) to 8.44 (84.4% of maximum; SD = 1.54). The reduction in standard deviation from pre-test to post-test suggests that post-intervention performance was not only higher but also more homogeneous, indicating that the intervention narrowed the initial performance dispersion among students.

Table 1. Descriptive statistics of pre-test and post-test science literacy scores (n = 32)

Variable	Mean	SD	Max Score
Pre-test	6.44	1.722	10
Post-test	8.44	1.544	10
Mean gain	+2.00	—	—

Science Literacy Gains per Indicator

Table 2 disaggregates pre-test, post-test, and N-Gain values across the three PISA science literacy indicators. All three indicators improved following the intervention; however, the magnitude and efficiency of gain differed substantially across indicators.

The "identifying scientific problems" indicator showed the smallest absolute gain (from 73.5% to 82.8%), with an N-Gain of 0.35 (moderate category). This relatively constrained gain is consistent with evidence that problem-identification skills, grounded in abstract thinking and prior domain knowledge, are less immediately responsive to short-duration interventions than evidence-based skills (Jannah, 2025).

The "explaining scientific phenomena" indicator showed a more substantial gain (from 68.7% to 88.3%), with an N-Gain of 0.63 (moderate category). The 19.6 percentage-point absolute gain on this indicator likely reflects the conceptual scaffolding provided by the flashcard media during the niti surti stage, which directly supported students' capacity to verbalise and connect physical phenomena to underlying scientific principles (Pan & Rickard, 2018).

The most pronounced gain was recorded on "using scientific evidence", which increased from 48.0% to 85.3%, yielding an N-Gain of 0.72 (high category). The 37.3 percentage-point absolute gain and high N-Gain on this indicator are noteworthy: this was the lowest-performing indicator at pre-test (48.0%), yet achieved one of the highest post-test scores (85.3%). The experimental character of the biogas project, which required students to collect observational data systematically and ground their conclusions in that evidence, directly trained the competency domain assessed by this indicator.

Table 2. Science literacy performance per indicator: pre-test, post-test, and N-Gain

Indicator	Pre-test mean	Pre (%)	Post-test mean	Post (%)	N-Gain	Category
Identifying scientific problems	2.94	73.5%	3.31	82.8%	0.35	Moderate
Explaining scientific phenomena	2.06	68.7%	2.65	88.3%	0.63	Moderate
Using scientific evidence	1.44	48.0%	2.56	85.3%	0.72	High
Overall	**6.44**	**64.4%**	**8.44**	**84.4%**	**0.58**	**Moderate**

Normality and Assumption Testing

Table 3 presents the results of the Shapiro–Wilk and Kolmogorov–Smirnov normality tests. Pre-test scores were normally distributed (Shapiro–Wilk: sig. = .340; Kolmogorov–Smirnov: sig. = .100; both > .05). Post-test scores were not normally distributed (Shapiro–Wilk: sig. = .000; Kolmogorov–Smirnov: sig. = .000; both < .05). The post-test non-normality likely reflects a ceiling concentration effect: 27 of 32 students (84.4%) showed improvement, with several approaching the maximum score, compressing the upper distribution. Accordingly, the non-parametric Wilcoxon Signed-Rank Test was employed for hypothesis testing.

Table 3. Shapiro–Wilk and Kolmogorov–Smirnov normality test results

Variable	Shapiro–Wilk sig.	K–S sig.	Decision	Distribution
Pre-test	0.340	0.100	sig. > .05	Normal
Post-test	0.000	0.000	sig. < .05	Not normal

Wilcoxon Signed-Rank Test and Effect Size

Table 4. Wilcoxon Signed-Rank Test results and effect-size estimate

Statistic	Value
N (total)	32
Positive ranks (post > pre)	27
Negative ranks (post < pre)	3
Ties (post = pre)	2
Z (Wilcoxon)	−4.112
p-value (Asymp. Sig. 2-tailed)	.000 (< .05)
Rank-biserial correlation, $r = \lvert Z \rvert / \sqrt{N}$	0.727 — Large effect (Cohen, 1988)
Decision	H_0 rejected; H_1 accepted

Table 4 presents the complete Wilcoxon Signed-Rank Test output and the effect-size estimate. Among the 32 students, 27 showed improvement (positive ranks), 3 declined (negative ranks), and 2 showed no change (ties). The Wilcoxon test yielded $Z = -4.112$, $p < .001$ (two-tailed), leading to rejection of the null hypothesis: the intervention produced a statistically significant improvement in science literacy scores.

The rank-biserial correlation effect size was $r = |Z| / \sqrt{N} = 4.112 / \sqrt{32} = 0.727$. By Cohen's (1988) benchmarks, this constitutes a large effect, indicating that the practical significance of the improvement substantially exceeds the minimum threshold for educational relevance. The overall N-Gain of 0.58 classifies the intervention's efficiency as moderate (Hake, 1998), consistent with a meaningful but not yet optimised learning programme.

Discussion

Pancaniti as an Inquiry and Constructivist Architecture

The statistically significant improvement and large effect size (r = 0.727) observed in this study provide empirical support for the pedagogical effectiveness of the Pancaniti model in elementary science contexts. This finding is explicable through a constructivist lens (Vygotsky, 1978): the five Pancaniti stages structure a progressive knowledge-building sequence in which students move from guided observation (niti harti) to autonomous communication of scientific claims (niti sajati), a progression that mirrors the zone of proximal development logic of scaffolded inquiry. The staged structure ensures that students do not encounter the full complexity of scientific reasoning without preparatory conceptual support.

The Pancaniti architecture also resonates with Kolb's (1984) Experiential Learning Cycle, which posits four sequential stages: concrete experience, reflective observation, abstract conceptualisation, and active experimentation. The mapping is direct: niti harti corresponds to concrete experience; niti surti to reflective observation and abstract conceptualisation; niti bukti to active experimentation; niti bakti to a second cycle of reflective observation; and niti sajati to the application and communication of consolidated understanding. This structural alignment explains why the Pancaniti model is not merely culturally distinctive but is also theoretically coherent with established learning science frameworks (Rachman et al., 2022).

Differential Indicator Effects: The Role of Evidence-Based Learning

The finding that the largest N-Gain occurred on the "using scientific evidence" indicator (0.72; high) rather than the arguably simpler "identifying scientific problems" indicator (0.35; moderate) is both practically and theoretically significant. It suggests that experiential, project-based pedagogies are disproportionately effective for higher-order science literacy competencies that require data collection, interpretation, and evidence-to-claim reasoning. This pattern corroborates Krajcik and Shin's (2014) argument that project-based science learning is especially powerful for competencies requiring sustained engagement with evidence across multiple time points.

The relatively modest gain on "identifying scientific problems" (N-Gain = 0.35) warrants targeted attention in future implementations. The pre-test score for this indicator was already the highest among the three (73.5%), so the limited gain is partly a ceiling effect. However, the structured problem-identification component of the intervention may also benefit from more explicit scaffolding for instance, through guided question-formulation protocols during the niti harti stage to produce gains commensurate with the other indicators.

Flashcard Media as Conceptual Scaffolding

The sharp improvement on "explaining scientific phenomena" (absolute gain: 19.6 percentage points; N-Gain = 0.63) is consistent with the role of the flashcard media as a conceptual retrieval scaffold during the niti surti stage. Pan and Rickard's (2018) meta-analysis established that retrieval practice enhances long-term conceptual retention more effectively than re-reading or passive review. By requiring students to actively recall definitions, process representations, and cause-effect chains on the flashcard, the intervention strengthened the conceptual schema required for scientific explanation tasks on the post-test. This finding corroborates Wati and Mahendra's

(2025) report of improved science outcomes associated with flashcard use in elementary classrooms, and Solissa et al.'s (2023) validation of flashcard media quality in supporting concept acquisition.

Alignment with Education for Sustainable Development

The selection of a simple biogas construction project as the hands-on component served a dual function: it provided the experimental substrate for the "using scientific evidence" competency, and it positioned the learning experience within an Education for Sustainable Development (ESD) frame (UNESCO, 2017). Students who construct a working anaerobic fermentation system do not merely learn about renewable energy as an abstract concept; they experience the causal chain from organic waste to biogas production, making the relationship between human behaviour, energy systems, and environmental sustainability tangible and personally meaningful.

This alignment with ESD is precisely where the Pancaniti model's grounding in Sundanese ecological values adds unique pedagogical value. The philosophical principle of tatanen cultivating a caring, reciprocal relationship with the natural environment that underpins the model (Alindra et al., 2025; Dinas Pendidikan Purwakarta, 2020) provides an affective and ethical dimension to the scientific inquiry that generic inquiry models typically lack. The result is an instructional sequence in which scientific competency development and ecological value formation are mutually reinforcing rather than competing objectives, consistent with the integrative vision of SDG 4.7 (UNESCO, 2017).

Practical Significance and Effect Size

The rank-biserial correlation of $r = 0.727$ places the observed effect in the large category under Cohen's (1988) conventions and in the top quartile of effect sizes reported in systematic reviews of elementary science intervention studies (Minner et al., 2010). This large effect size is notable given the one-group design and the relatively short intervention window, and it should be interpreted alongside the design's internal validity limitations described below. Nevertheless, it suggests that the combined Pancaniti-Flashcard-Biogas intervention constitutes a practically meaningful instructional innovation worthy of further evaluation in controlled designs.

Limitations

Four limitations must be acknowledged. First, the absence of a control group precludes causal inference: the observed gains may partially reflect maturation, repeated testing, or history effects rather than the intervention alone. Future research should employ a non-equivalent control group or, ideally, a randomised assignment design to isolate intervention effects. Second, the sample was drawn from a single school through purposive sampling, limiting the generalisability of findings to other socioeconomic, geographic, and cultural contexts. Third, the intervention was implemented by the researcher alongside the class teacher; implementation fidelity in purely teacher-delivered conditions may differ.

CONCLUSION

This study provides evidence that the Pancaniti learning model, when combined with flashcard visual media and a hands-on simple biogas project, produces statistically significant and practically large improvements in science literacy among Grade 5 elementary school students (Wilcoxon $Z = -4.112$, $p < .001$; $r = 0.727$; N-Gain = 0.58). Gains were observed across all three PISA science literacy indicators, with the greatest efficiency of gain recorded for "using scientific evidence" (N-Gain = 0.72; high), reflecting the evidential demands of the biogas project. The instructional design's strength lies in its structural coherence: the Pancaniti stages scaffold an experiential learning cycle grounded in Sundanese ecological values, while the flashcards and biogas project respectively operationalise conceptual consolidation and inquiry-based evidence collection. Future research should test this intervention in a controlled or randomised design, expand the sample to multiple schools, and investigate long-term retention of science literacy gains. Curriculum developers and teacher educators in Indonesian madrasah and public elementary school contexts are encouraged to consider the Pancaniti-Flashcard-Biogas model as a scalable, culturally responsive approach to sustainability-oriented science instruction.

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