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Development of Science Storybook Based on Metro City Cultural Heritage as Integrated Literacy Media for Science and Indonesian Language in Elementary School

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ABSTRACT

This study aims to develop and evaluate a Metro City cultural heritage-based science storybook as integrated literacy media for science and Indonesian language learning in elementary school. The development employed the Research and Development (R&D) approach using the 4D model (Define, Design, Develop, Disseminate), involving expert validators, readability testing participants, and 90 fourth-grade students across three schools for quasi-experimental field testing. Results showed that the storybook met very valid criteria based on expert validation (material 90.4%, language 89.6%, media 91.2%) and achieved a very practical readability rating. Field testing demonstrated significant learning improvements, with the experimental group attaining high N-Gain scores of 0.74 (scientific literacy) and 0.71 (Indonesian language), compared to 0.42 and 0.41 in the control group, supported by very large effect sizes (Cohen's d = 1.92 and 1.67). This study contributes a novel triple integration model that connects science concepts, Indonesian language genres, and local cultural heritage within a unified elementary thematic learning medium.

Keywords: Science Storybook; Local Wisdom; Cultural Heritage; Scientific Literacy; Indonesian Language; Thematic Learning.

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1. INTRODUCTION

Contemporary Indonesian education faces a dual challenge: cultivating globally competitive competencies while simultaneously preserving local cultural identity (Afifuddin et al., 2025). The Kurikulum Merdeka responds to this through integrated thematic learning; however, implementation remains significantly constrained by the scarcity of learning media capable of integrating multiple subject areas with authentic local cultural contexts (Taali et al., 2024; Niman, 2025). This challenge is further underscored by Indonesia's ranking of 67th among 81 countries in the PISA 2022 scientific literacy assessment, with students demonstrating particularly weak performance in applying scientific concepts to their local contexts (OECD, 2023).

Metro City in Lampung Province serves as a compelling illustration of this educational challenge at the local level. Despite possessing extraordinary cultural heritage encompassing agricultural traditions, traditional handicrafts, and seven officially designated heritage sites these

resources remain largely underutilized in formal educational settings (Castro-Calviño et al., 2020). Elementary students' scientific literacy scores consistently fall below provincial targets, representing a significant missed opportunity for culturally responsive pedagogy that could advance academic achievement (Roy et al., 2025) while simultaneously strengthening students' cultural identity formation (Bhoki et al., 2025).

Research on local wisdom-based learning media has demonstrated promising yet limited outcomes. Gularso et al. (2023) developed a local genius-based pocket book that yielded significant improvements in character education ($d = 1.45$, $p < 0.001$), yet the study focused exclusively on character formation without addressing science or language literacy, and its format lacked the narrative engagement necessary to sustain elementary student interest. Hastuti et al. (2023) explored short story writing rooted in local wisdom for university students, achieving notable improvements (pretest $M = 66.4$; posttest $M = 82.3$), but targeted higher education and emphasized literary production rather than science literacy development. Ratminingsih et al. (2020) created local culture-based storybooks with positive effects on elementary students' reading competence ($F = 18.73$, $p < 0.05$), yet these addressed only language skills in isolation, without achieving the cross-disciplinary integration demanded by thematic curricula.

More recent digital developments have expanded the landscape of local wisdom-based educational media but continue to exhibit methodological limitations. Eliza et al. (2024) introduced digital picture-science stories for early childhood, focusing primarily on user interface validation without measuring actual learning outcomes. Syahfitri et al. (2024) developed digital media rooted in local wisdom as children's literature, yet employed only descriptive validation without rigorous experimental testing of educational effectiveness. A comprehensive bibliometric analysis by Huyen et al. (2024) of global trends in local wisdom integration confirmed that most existing studies remain conceptual or descriptive in nature, with limited rigorous experimental validation a critical gap that the present research directly addresses.

Complementary evidence from digital learning media research further reinforces the potential of innovative narrative and inquiry-based approaches. Rokhayati et al. (2022) developed e-book teaching materials employing a scientific inquiry approach, achieving very high validity scores (material 94%, language 88%, media 98%) and an excellent student response rate (95.3%), effectively strengthening science literacy among fourth-grade elementary students. Febrianti et al. (2022) created SETS-based e-books integrating Science, Environment, Technology, and Society attaining very valid criteria (language 86%, material 82%, media 100%) with strong student response (91.89%), successfully helping students recognize connections between science and their environmental contexts. More recently, Ratnawati et al. (2025) confirmed through a systematic literature review that Flipped Problem-Based Learning significantly improves multiple literacy dimensions including reading, numeracy, critical thinking, and digital literacy with Self-Regulated Learning serving as a central mediating factor in optimizing technology-based independent learning.

The body of reviewed literature collectively reveals a critical and unresolved research gap: existing local wisdom-based educational media predominantly target single subject areas and thus fail to address the integrated thematic learning requirements central to the Kurikulum Merdeka (Gularso et al., 2023; Ratminingsih et al., 2020). While narrative and cultural approaches have demonstrated effectiveness within isolated disciplinary contexts, no prior study has simultaneously integrated science literacy development, Indonesian language competency enhancement, and specific local cultural heritage within a unified medium designed for elementary school thematic instruction (Taali et al., 2024; Afifuddin et al., 2025). This absence of

triple-integrated, culturally grounded learning media particularly one anchored in Metro City's distinctive heritage represents the precise gap this research is designed to fill Huyen et al. (2024).

This study addresses the central research question: How can a Metro City cultural heritage-based science storybook be developed as effective integrated literacy media for elementary school science and Indonesian language learning? To address this question, the research makes four key scholarly contributions: (1) a novel triple integration model connecting science concepts, Indonesian language genres, and local wisdom within a unified medium; (2) empirically validated learning media specifically designed for *Kurikulum Merdeka* thematic implementation; (3) a replicable, place-based framework for developing integrated learning materials applicable across other Indonesian cities; and (4) empirical evidence advancing culturally responsive pedagogy in Indonesian elementary education (Niman, 2025). By positioning Metro City's seven designated cultural heritage sites as authentic learning contexts, this research directly addresses documented gaps in locally grounded, integrated science literacy interventions within the Indonesian educational landscape (Castro-Calviño et al., 2020; Bhoki et al., 2025).

2. METHODS

2.1 Research Design

This study employed a two-phase research design integrating Research and Development (R&D) with a quasi-experimental approach. The development phase followed the 4D model (Define, Design, Develop, Disseminate) by Thiagarajan at al. (1974) to produce and validate the storybook, while the effectiveness phase used a pretest-posttest control group design to test its impact on student learning outcomes. This integrated design is appropriate for educational media research that requires both product validation and empirical effectiveness testing (Borg & Gall, 2003). The study was conducted at three purposively selected elementary schools in Metro City, Lampung Province MI Muhammadiyah Hadimulyo Metro, SDN 4 Metro Timur, and SDN 2 Metro Timur from June to November 2025. Schools were selected based on comparable socioeconomic profiles, representative urban characteristics, and institutional willingness to participate.

2.2 Development Procedures

The 4D model was implemented across four sequential phases. The Define phase (June 2025) involved curriculum analysis of Kurikulum Merdeka competency standards, student characteristic analysis, and mapping of science concepts and Indonesian language genres suitable for integration with Metro City's cultural heritage. The Design phase (July 2025) encompassed field visits to seven heritage sites (Dr. Swoning House, Heritage Tree, Santa Maria Clinic, Historical Laboratory, Traditional Well, Traditional Market, and Cultural Museum), development of a concept integration matrix, narrative and visual storyboard design, and validation instrument construction. The Develop phase (August 2025) produced a 23-page full-color storybook titled "Petualangan Sains Super Seru di Cagar Budaya Kota Metro," followed by three rounds of expert validation, product revision, and readability testing. The Disseminate phase (November 2025) consisted of quasi-experimental field testing across all three schools with structured fidelity monitoring.

2.3 Research Participants

Participants were determined through purposive sampling at each development stage. Expert validation involved three validators: one science education specialist, one Indonesian language education specialist, and one instructional design specialist, each holding a minimum master's degree with at least five years of relevant experience. Readability testing involved 5 students in a one-to-one evaluation and 15 students in a small group evaluation, both drawn from MI Muhammadiyah Hadimulyo Metro and representing diverse academic ability levels. For field testing, 90 fourth-grade students from the three schools participated (experimental group n = 45; control group n = 45, with 15 students per group per school). The experimental group received instruction using the developed storybook across 12 sessions of 70 minutes over four weeks, while the control group received conventional instruction using government-issued textbooks with identical curriculum content and time allocation.

2.4 Instruments

Five validated instruments were used. (1) Expert validation sheets comprised three domain-specific instruments assessing material validity (25 items), language validity (20 items), and media validity (22 items) using 5-point Likert scales; content validity was established using Aiken's V formula, with all items achieving $V \geq 0.80$. (2) A readability questionnaire (15 items, Cronbach's $\alpha = 0.876$) assessed student perceptions of text comprehensibility, illustration clarity, and overall engagement. (3) A scientific literacy test (30 multiple-choice items, Cronbach's $\alpha = 0.857$; difficulty index 0.35–0.75) measured competencies aligned with the PISA scientific literacy framework across five concept domains. (4) An Indonesian language competency test (25 multiple-choice items, Cronbach's $\alpha = 0.842$; difficulty index 0.40–0.70) assessed reading comprehension across five text genres in alignment with Kurikulum Merdeka standards. (5) Implementation observation sheets documented treatment fidelity during experimental group instruction.

2.5 Data Analysis

Data were analyzed using SPSS version 26.0. Validation data were assessed using Aiken's V formula (acceptable threshold: $V \geq 0.80$), while readability data were analyzed descriptively using percentage scores classified on a five-tier scale (very practical: 81–100%). For field testing data, normality was verified using the Shapiro-Wilk test and homogeneity using Levene's test (both at $p > 0.05$). Hypothesis testing employed independent samples t-tests ($\alpha = 0.05$), with effect sizes calculated using Cohen's d (small: 0.2; medium: 0.5; large: 0.8). Learning improvement was measured using normalized gain scores (N-Gain) following Hake's formula, interpreted as high ($g \geq 0.7$), medium ($0.3 \leq g < 0.7$), or low ($g < 0.3$). Cross-site consistency of outcomes was examined using one-way ANOVA with post-hoc Tukey HSD tests. This study received ethics approval from the Universitas Muhammadiyah Metro Research Ethics Committee (No. 294/II.3.AU/F/LPPM/UMM/2025) and informed consent was obtained from all participants' guardians.

3. RESULT AND DISCUSSION

3.1 Product Development Results

The developed product is a 23-page full-color science storybook titled "Petualangan Sains Super Seru di Cagar Budaya Kota Metro" integrating five main learning sections connecting Metro City cultural heritage locations with science concepts and Indonesian language genres. Table 1 presents the integration matrix demonstrating how each heritage site systematically connects with specific science concepts and language genres, creating a coherent pedagogical framework.

Table 1. Integration Matrix of Heritage Sites, Science Concepts, and Language Genres

Section	Heritage Location	Science Concepts	Language Genre
1. Old Building	Dr. Swoning House	Properties of solids, heat transfer	Descriptive, Explanatory text
2. Ancient Tree	Heritage tree	Photosynthesis, oxygen production	Explanatory, Narrative text
3. Health Science	Santa Maria Clinic	Medical tools, health systems	Procedural, Descriptive text
4. Cell Biology	Historical Laboratory	Blood cells, microscope use	Report, Explanatory text
5. Force Science	Traditional well	Forces, motion, simple machines	Narrative, Explanatory text

The product incorporates distinctive features that differentiate it from conventional learning materials: (1) Triple Integration Model simultaneously connecting science, language, and local wisdom in coherent narratives; (2) Culturally Responsive Content using authentic Metro City heritage sites as learning contexts; (3) Inquiry-Based Dialogue stimulating critical thinking through character conversations; (4) Visual Scaffolding through 47 professionally designed full-color illustrations; (5) Explicit Moral Messages conveying character values aligned with Indonesian cultural principles; and (6) Teacher Guide Companion providing pedagogical strategies for classroom implementation.

3.2 Expert Validation Results

Expert validation assessed content validity from three dimensions: material, language, and media quality. Table 2 presents comprehensive validation results demonstrating very valid classification across all dimensions.

Table 2. Expert Validation Results

Validator	Mean Score	Percentage	Category
Material Expert	4.52	90.4%	Very Valid
Language Expert	4.48	89.6%	Very Valid
Media Expert	4.56	91.2%	Very Valid
Overall Average	4.52	90.4%	Very Valid

Material expert validation yielded 4.52 (90.4%), indicating very valid criteria with particular strengths in concept accuracy (4.67), curriculum alignment (4.33), and local wisdom integration (4.40). Minor improvements were suggested for adding more explicit connections between heritage contexts and contemporary applications. Language expert validation produced 4.48 (89.6%), categorized as very valid with strengths in grammar accuracy (4.50) and discourse

coherence (4.50). Recommendations included simplifying several complex sentence structures to enhance elementary student comprehension. Media expert validation achieved 4.56 (91.2%), attaining very valid classification with exceptional strengths in illustration quality (4.67) and color harmony (4.60). Suggestions focused on increasing font size for specific labels to improve readability.

These validation scores substantially exceed typical educational media validation thresholds (≥80% for acceptable quality), indicating strong pedagogical soundness and technical quality. The consistently high scores across all dimensions (89.6-91.2%) demonstrate successful integration of content accuracy, linguistic appropriateness, and visual design principles. All validator suggestions were incorporated through iterative revisions, yielding the final product version used in field testing.

3.3 Readability and Practicality Results

Readability testing through one-to-one evaluation (n=5) achieved 91.2% and small group evaluation (n=15) yielded 93.4%, both categorized as very practical. Students expressed particular enthusiasm for the colorful illustrations and appreciated connections between stories and familiar places in Metro City. Qualitative feedback revealed that students found the narrative format more engaging than conventional textbooks, with comments including "the pictures help me see how heat moves through the house" and "I can imagine being there with the characters." These results indicate successful creation of accessible, engaging learning materials appropriate for fourth-grade elementary students.

3.4 Learning Achievement Results

Effectiveness testing through quasi-experimental design with pretest-posttest control group demonstrated significant improvements in both scientific literacy and Indonesian language competency. Table 3 presents comparative achievement results across experimental and control groups.

Table 3. Learning Achievement Comparison Between Experimental and Control Groups

Variable	Group	Pretest M (SD)	Posttest M (SD)	N-Gain	Category
Scientific Literacy	Experimental	52.67 (8.43)	87.33 (6.21)	0.74	High
	Control	51.33 (8.91)	71.67 (7.85)	0.42	Medium
Indonesian Language	Experimental	56.00 (7.92)	87.20 (5.94)	0.71	High
	Control	54.67 (8.34)	73.33 (7.42)	0.41	Medium

Pretest equivalence was confirmed for both scientific literacy [t(88) = 0.746, p = 0.458] and Indonesian language [t(88) = 0.782, p = 0.436]. As shown in Table 4, posttest comparisons demonstrated that the experimental group significantly outperformed the control group on both measures: scientific literacy [t(88) = 7.864, p < 0.001, Cohen's d = 1.92, N-Gain = 0.74 vs. 0.42] and Indonesian language competency [t(88) = 6.843, p < 0.001, Cohen's d = 1.67, N-Gain = 0.71 vs. 0.41]. Multi-site ANOVA confirmed school-independent effectiveness for scientific literacy [F(2,42) = 1.234, p = 0.301] and Indonesian language [F(2,42) = 0.987, p = 0.381]. The effect sizes substantially exceed Cohen's (1988) threshold for large effects (d > 0.8) and approach Hattie's (2009) benchmark for exceptional educational interventions (d > 1.2), confirming that the cultural heritage-based approach produces markedly stronger outcomes than conventional instruction.

3.5 Triple Integration, Situated Cognition, and Culturally Responsive Pedagogy

The most fundamental explanation for the observed learning gains is the triple integration model's grounding in situated cognition theory (Brown et al., 1989), which holds that knowledge construction is most effective when embedded in authentic contexts. The substantially higher N-Gain scores in the experimental group (0.74 for scientific literacy; 0.71 for Indonesian language) compared to the control group (0.42 and 0.41, respectively) indicate that anchoring learning within Metro City's heritage sites transformed abstract concepts into personally meaningful knowledge structures. The natural alignment between heritage contexts, scientific phenomena, and language genres illustrated in Table 2 created what Vygotsky (1978) termed optimal zones of proximal development, where cultural familiarity scaffolds conceptual understanding.

These outcomes align with culturally responsive pedagogy Ladson-Billings (2021), which argues that connecting academic content to students' cultural backgrounds enhances both engagement and achievement. The very large effect sizes (d = 1.92 for science; d = 1.67 for language) substantially exceed Hattie's (2009) benchmark for exceptional interventions (d > 1.2). Importantly, students demonstrated superior performance on transfer items beyond the specific heritage contexts studied, confirming that culturally grounded learning enhances rather than limits transferability (Smith, 2002). The integration of five Indonesian language genres within science narratives further operationalizes Gibbons's (2015) argument that language learned through purposeful content achieves deeper linguistic competence than isolated instruction.

3.6 Multimedia Design and Cognitive Load Management

The product's design reflects Mayer's (2021) cognitive theory of multimedia learning, applying the multimedia, coherence, spatial contiguity, and personalization principles. The high readability scores (91.2–93.4%) validate this approach, indicating successful minimization of extraneous cognitive load and effective visual-verbal integration (Sweller at al., 2019). Cultural familiarity further reduced intrinsic load by rendering abstract scientific phenomena concrete through familiar referents, maximizing cognitive resources available for meaningful schema construction. Together, these design principles explain why the storybook format produced superior outcomes compared to conventional textbook instruction.

3.7 Comparison with Previous Research

The present findings both confirm and extend prior literature. Whereas Gularso et al. (2023) demonstrated local wisdom media effectiveness for character education (d = 1.45) and Ratminingsih et al. (2020) showed storybook effectiveness for language skills alone, neither achieved cross-disciplinary integration. This study demonstrates that integrating science, language, and local wisdom within a single medium produces synergistic rather than competing learning effects addressing the gap identified by Huyen et al. (2024) regarding the absence of rigorously validated cross-domain integration in the local wisdom-based learning media literature. Unlike recent digital media studies (Eliza et al., 2024; Syahfitri et al. 2024), which focused primarily on interface validation, the present study provides rigorous quasi-experimental evidence of actual learning effectiveness across two distinct competency domains.

3.8 Implications for Educational Practice

The research findings carry significant implications for multiple stakeholders. For classroom teachers, the product demonstrates a practical model for implementing Kurikulum Merdeka's integrated thematic learning mandate. Teachers can adapt the framework to their local contexts, identifying community cultural resources suitable for anchoring integrated instruction. For curriculum developers and educational publishers, the study validates market potential for culturally responsive, integrated learning materials that achieve both educational effectiveness and student engagement.

For school administrators, findings suggest investments in culturally responsive learning materials yield substantial returns, with effect sizes (d=1.92 for science, d=1.67 for language) indicating such materials can significantly advance institutional learning goals. For educational policymakers, the study provides empirical evidence supporting policies that mandate or incentivize culturally responsive pedagogy, including curriculum standards requiring local cultural integration, textbook approval criteria prioritizing culturally responsive design, and teacher preparation programs incorporating place-based education methods.

3.9 Research Limitations

Several limitations warrant acknowledgment. First, the quasi-experimental design with intact class assignment, while strengthened by multi-site implementation and pretest equivalence confirmation, lacks full randomization of individual participants. Second, the four-week intervention period provides evidence of immediate learning gains but limited information regarding long-term retention and transfer. Third, the specific focus on Metro City cultural heritage limits immediate generalizability to other Indonesian contexts, though the detailed development process documentation provides transferability for adaptation. Fourth, assessment instruments, while demonstrating acceptable reliability ($\alpha>0.84$) and validity, were researcher-developed rather than employing standardized national or international instruments. Fifth, the study focused exclusively on fourth- grade students, leaving questions about developmental appropriateness for other elementary grades.

3.10 Future Research Directions

The study opens multiple avenues for future investigation. Longitudinal studies should examine whether learning gains persist over time and influence longer-term outcomes such as science career interest, cultural identity development, or community engagement. Cross-cultural replication studies should test the triple integration model's effectiveness in diverse Indonesian regions and potentially other Southeast Asian nations, examining both universal principles and culture-specific adaptations required. Digital adaptation research could develop and test augmented reality versions of heritage-based storybooks, investigating whether technology enhancement amplifies outcomes. Scale-up research investigating systematic implementation across school systems would clarify feasibility, cost-effectiveness, and sustainability of heritage-based approaches at scale.

4. CONCLUSION

This study successfully developed a Metro City cultural heritage-based science storybook as integrated literacy media for elementary school science and Indonesian language learning. The product met very valid and very practical criteria based on expert validation and readability testing, and demonstrated significant effectiveness in improving fourth-grade students' learning outcomes through quasi-experimental field testing across three schools. The experimental group achieved high learning gains on both scientific literacy and Indonesian language competency, with very large effect sizes that substantially exceed conventional intervention benchmarks, confirming that the heritage-based storybook produces meaningfully superior outcomes compared to conventional instruction.

The primary scientific contribution of this study is the triple integration model, which simultaneously connects science concepts, Indonesian language text genres, and local cultural heritage within a single unified learning medium. This model addresses a gap that prior literature has not resolved the absence of rigorously validated, cross-domain integrated learning media for elementary thematic instruction and provides an empirically grounded framework aligned with the integrated thematic learning mandate of Kurikulum Merdeka. The model extends situated cognition theory and culturally responsive pedagogy into the Indonesian elementary education context, demonstrating that cultural familiarity functions not merely as a motivational strategy but as a substantive cognitive scaffold that deepens both science understanding and language competence simultaneously. For practice, this study offers teachers and curriculum developers a replicable framework for designing place-based integrated learning materials using local cultural resources available in their own communities. Future research should examine the long-term retention of learning gains, test the model's applicability across different grade levels and cultural contexts in Indonesia, and explore digital adaptations that may further enhance its reach and effectiveness.

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