Jurnal Genesis Indonesia
Vol. 5, No. 03, pp. 289-307
journal.iistr.org/index.php/JGI
DOI: 10.56741/IISTR.jgi.002867

Ecostorytelling in Primary Science Education: An Integrated Framework Linking Local Ecology, Scientific Inquiry, Numeracy, and Environmental Agency

[1]Erika Fitri Wardani, [2]Ika Maryani*, [1]Asyraf Suryadin
Corresponding Author: * ika.maryani@uad.ac.id
[1] Universitas Muhammadiyah Bangka Belitung, Indonesia
[2] Universitas Ahmad Dahlan, Yogyakarta, Indonesia

ARTICLE INFO

Article history
Received 30 October 2026
Revised 13 November 2026
Accepted 16 November 2026

ABSTRACT

This conceptual study develops an evidence-sensitive ecostorytelling framework for primary science education by integrating locally meaningful ecological phenomena, narrative problematisation, scientific inquiry, quantitative reasoning, cultural reflection, and feasible environmental action. A structured conceptual synthesis was conducted using a bounded corpus of 20 studies documented in the source manuscript, complemented by theoretical and methodological literature for interpretation. The synthesis distinguished empirical evaluations, qualitative investigations, literature reviews, and conceptual or text-analytic studies, and examined the support and limitations for each proposed design component. Five recurring findings emerged: local ecological contexts can make inquiry meaningful but require careful curricular alignment; stories may elicit questions without guaranteeing conceptual learning; investigation must produce interpretable evidence; numeracy needs explicit tasks and assessment; and environmental agency depends on feasible, socially supported action rather than awareness alone. The resulting six-stage framework specifies a sequence from local phenomenon mapping to narrative framing, inquiry planning, evidence interpretation, cultural reflection, and collective action. Five propositions and an assessment strategy are offered for future empirical examination. Because the framework has not been field-tested as an integrated intervention, claims about improved science

literacy, numeracy, or sustained behaviour remain hypotheses. The contribution is a transparent, testable instructional design proposition rather than an effectiveness claim.

Keywords
Ecostorytelling
Environmental Agency
Inquiry-Based Science Education
Local Ecological Knowledge
Place-Based Learning

This is an open-access article under the CC–BY-SA license.

Introduction

Primary science education is expected to help children make sense of phenomena, use evidence, and connect scientific ideas to situations beyond the classroom. Yet science can become disconnected from children's lived experience when content is presented as isolated facts. Place-based learning offers one response by treating the local environment and community as resources for meaningful questions, inquiry, and civic engagement. A recent systematic review of 68 studies in K–12 science education identified authentic inquiry, engagement with social transformation, and integration of local knowledge as recurring aims and practices. It also identified implementation challenges: alignment with standards, teachers' capacity to enact place-based pedagogy, differences in students' sense of place, and limited support from school and community partners [4]. These findings support the relevance of local context, but the review authors explicitly caution that their synthesis maps practices and objectives rather than establishing a general causal effect of place-based learning.

Environmental education research also suggests that nature-rich experience and opportunities for age-appropriate action matter. A recent review of school-based environmental education further highlights the need to examine teacher practices and implementation conditions rather than assuming that environmental education approaches operate uniformly across contexts [25]. Ardoin and Bowers [1], in a mixed research synthesis of 66 early-childhood environmental education studies, identified time in nature and action-taking as common practices, while noting that action-taking was not always prioritised in guidelines. Their review included studies reporting cognitive, language and literacy, social-emotional, physical, and environmental-literacy outcomes. However, its age range was birth to eight, its search was limited to English-language empirical studies, and no studies from Latin America or Africa met its inclusion criteria. The findings therefore offer useful principles rather than a complete picture of environmental education across contexts.

Narrative is another promising resource. Stories can organise events around characters, motives, consequences, and change, giving learners a way to relate scientific phenomena to lived experience. Picturebooks can act as invitations, provocations, models, resources, and destinations in inquiry-based learning [15]. A theoretical review of science narration, however, found that the benefits of narrative were inconsistent across the literature; a later review similarly emphasises the need to balance narrative appeal with scientific accuracy and stronger empirical evaluation [9]. Narrative texts were not invariably superior to expository texts, and effects depended on features of the text, learner, activity, and context [23]. Thus, storytelling should not be treated as an automatic learning enhancer.

Environmental storytelling can also support emotional engagement and agency when stories model achievable responses rather than only presenting crisis. In a study of nine workshops across seven primary schools in southwest England, Portus et al. [17] used a bee-centred story combined with dance and practical activities. Children's survey responses and group discussions indicated enthusiasm for further environmental learning, perceived agency, and intentions to take pro-environmental action. This is encouraging but bounded evidence: the study investigated a specific action-based storytelling workshop, not a general model for science literacy or numeracy, and intentions do not establish sustained behaviour.

The literature reviewed here does not yet provide a validated, integrated design framework specifying how a locally grounded ecological story should lead into scientific inquiry, explicit numeracy, culturally responsive interpretation, and realistic environmental action in primary science. The elements are represented across different strands of research, but their relationships are not consistently operationalised together. Place-based learning research examines local knowledge and inquiry; narrative research examines comprehension and explanation; environmental education research examines engagement, identity, and action; and picturebook studies often analyse texts rather than learner outcomes. These strands cannot simply be combined as though they constituted evidence for one tested intervention.

A second uncertainty concerns literacy and numeracy. A systematic review of socioscientific-issues teaching in primary and secondary contexts found that environmental and sustainability issues recur in the literature, while evidence-based reasoning and classroom discussion are important pedagogical features; however, the review maps how teaching is enacted rather than establishing the effect of this proposed framework [7]. Scientific literacy requires learners to interpret explanations and evidence, while numeracy can involve counting, measuring, comparing, representing data, and reasoning about quantity in context. The supplied literature includes references to cognitive and mathematical concepts within early-childhood environmental education [1], and to inquiry and formative assessment in place-based science [4]. Yet the set does not establish that eco-storytelling improves both literacy

and numeracy as distinct outcomes. A conceptual framework must therefore identify where these outcomes may be developed and how they should be assessed, without reporting them as demonstrated effects.

A third uncertainty concerns local wisdom. Local ecological knowledge may enrich a phenomenon's cultural and practical significance, but it should not be romanticised or used as a substitute for scientific investigation. The framework needs a process for documenting whose knowledge is included, checking claims against evidence, recognising differences within communities, and avoiding unsupported claims that any local tradition is inherently sustainable.

Several recent reviews provide a strong foundation but also show why an integrated, testable framework is needed. Oberman's [15] review included 15 studies of picturebooks in inquiry-based education and described multiple functions that books can serve in inquiry. Ge et al. [4] synthesised 68 studies of place-based learning in K–12 science and identified recurring practices and barriers. Portus et al. [16] reviewed research on the environmental value–action gap and questioned assumptions that knowledge and positive attitudes reliably translate into behaviour. Soares et al. [23] reviewed 36 studies on narrating science and found mixed evidence about learning benefits. Together, these reviews caution against treating narrative, place, awareness, or action as isolated solutions.

Other studies illuminate specific mechanisms. Simms and Shanahan [22] examined environmental identity development among 35 sixth-grade students using interviews and reflective journals; their analysis highlights action with peers, emotion, agency, personal meaning, and social recognition. Harris et al. [5] studied how 12 elementary teachers adapted phenomena in two storyline units and found that teachers made local additions, while also identifying challenges in accessing knowledge about community resources. Häggström [7] used a six-week storyline approach in two primary classes to explore agency in sustainability education. These studies offer design insights, but their contexts and methods differ; none validates the complete framework proposed here.

A further caution comes from research on environmental picturebooks. Freitas et al. [3] analysed ocean-themed picturebooks for their potential to promote ocean literacy and awareness of a local marine environment. Knauf [11] examined environmental and climate nonfiction picturebooks, showing how they bridge children's experience and scientific information while also assigning responsibility to children and families. Rybak [19], analysing four green informational picturebooks, argued that action lists may encourage participation but can also offer idealised actions and little critical engagement. These are text-focused analyses, not direct demonstrations of changes in children's knowledge or behaviour.

The novelty of this article is not the claim to be the first to combine narrative and science. Recent reviews already examine narrative-centred learning and phenomenon-based storylines (Jiménez-Valverde, 2025; Walker & Nouri, 2025). Instead, the contribution is a design-oriented synthesis that makes the proposed links among local ecology, narrative, evidence-generating inquiry, explicit numeracy, cultural reflection, and environmental agency visible and assessable. It also makes the evidentiary status of each link explicit: the framework is a conceptual proposition for design and testing, not an intervention proven to improve literacy, numeracy, or environmental behaviour.

The contribution is a design framework that explicitly connects local ecological phenomena and local knowledge with narrative framing, evidence-generating inquiry, visible numeracy, cultural and ethical reflection, and feasible environmental agency. It is offered as a conceptual proposition for empirical testing, not as a validated intervention.

The article addresses the following research question: How can findings from research on place-based science, narrative learning, inquiry, and environmental education be synthesised into a conceptually coherent and empirically testable ecostorytelling framework for primary science education?

The present contribution is particularly concerned with the connection between educational design and the kind of evidence used to justify pedagogical claims. A local experience can be engaging without supporting a defensible scientific explanation; a story can be memorable without increasing understanding; and an environmentally responsible intention may remain unfulfilled where children lack material resources or institutional support. These distinctions require a design that explicitly treats the narrative as an invitation to formulate questions, not as a substitute for observation, conceptual explanation, or critical deliberation [26], [28], [29].

Place-conscious education also requires attention to power and access. A seemingly common local environment is not necessarily experienced similarly by all pupils: differences in mobility, language, family livelihood, disability, or exposure to ecological hazards can change what is familiar and safe. Gruenewald's multidimensional account of place cautions against reducing the local setting to physical geography alone [27]. Consequently, an inclusive ecostorytelling design should document whose perspectives have been represented and whether children can participate without having to disclose sensitive household or community experiences.

Materials and methods

A. Study design and corpus

This study used a structured conceptual literature synthesis rather than an empirical intervention or a systematic review claiming exhaustive coverage. The source set comprised

20 papers supplied for this project. It included systematic and semi-systematic reviews, theoretical papers, qualitative studies, mixed-methods workshop research, program evaluations, and studies of picturebooks, place-based science, phenomenon-based storylines, and environmental identity. The corpus was deliberately heterogeneous because the research question concerns the conceptual relationships among several related strands.

B. Analytical procedure

The synthesis proceeded in four steps. First, each paper was classified by publication type, educational setting, method, and primary focus. Second, the reported findings were extracted under five analytical headings: (1) place and local ecological context; (2) narrative and story structure; (3) inquiry, evidence, and science explanation; (4) literacy/numeracy and assessment; and (5) agency, reflection, and action. Third, limitations reported by the authors were considered when deciding how far a finding could support a framework component. Fourth, recurring concepts and tensions were integrated into a proposed sequence of design principles and propositions for future empirical testing.

The original corpus was maintained as a bounded evidence set rather than retrospectively portrayed as a newly conducted database search. The supplementary sources cited in the expanded discussion provide background conceptual or methodological support; they are not additional studies screened into the 20-paper evidence audit. Thus, the source corpus and the broader theoretical bibliography have different roles and must not be merged into a falsely exhaustive review sample. This distinction is important for reproducibility and for avoiding inflated claims of review coverage.

The conceptual synthesis was informed by an interpretive thematic logic in which recurring ideas are systematically organised, compared with disconfirming examples, and translated into design propositions. Braun and Clarke's methodological account provides a useful reference point for making interpretation explicit [30]; it does not imply that the original source manuscript conducted independent intercoder agreement testing or formal thematic saturation. In this article, conceptual coherence is assessed through traceable links among pedagogical problem, proposed mechanism, observable classroom activity, and possible assessment evidence.

C. Inference boundaries and transparency

The synthesis did not calculate pooled effects, estimate effect sizes, or rank intervention effectiveness. It did not use a formal risk-of-bias instrument across all designs, and the 20-paper corpus should not be described as exhaustive. The studies vary in age group, national context, duration, research design, and outcome measure. Some are conceptual or text-analytic and cannot support claims about learner outcomes. Where the source material did not establish a particular result or limitation, no numerical or causal claim was inferred.

Bibliographic metadata and DOI strings were cross-checked against publisher pages and public DOI metadata where available; journal quartiles were treated as a separate, year- and category-specific metric rather than as a proxy for the quality of an individual article.

Because the article is conceptual, there were no human participants, research site, intervention, or primary data-collection instruments. The unit of analysis was the published paper. The analysis was a qualitative thematic synthesis, and the resulting framework should be understood as a set of propositions requiring review and empirical validation.

No intervention participants, classrooms, pre-test/post-test scores, or effect estimates were generated. Accordingly, Results reports the analytical products of the synthesis, including design components, instructional phases, and testable propositions. Discussion considers their interpretation and limits. This separation follows the logic of IMRAD while recognising that a conceptual article does not have outcome data analogous to an experimental trial.

Results

A. Local ecological context

The first framework component is a phenomenon that children can recognise, observe, and investigate in or around their community. Suitable starting points might include changes in local water quality, seasonal flooding, heat and shade, waste accumulation, pollinator activity, coastal erosion, garden biodiversity, or changing availability of freshwater. The phenomenon should be locally meaningful but also scientifically tractable: children should be able to formulate questions, collect or inspect evidence, and distinguish observations from explanations.

The place-based literature supports the principle of contextual relevance. Ge et al. [4] found that authentic inquiry, embodied experience, community-based projects, and place-based socioscientific issues recur in K–12 science education. [18], evaluating four place-based education programs through interviews and field observations, documented perceived value in connecting learning with local environments and community contexts. Ballantyne and Packer [2], studying 12 environmental education programs across 16 classes, highlighted real-life learning, local context, personal connections, higher-order thinking, and sensory engagement as productive features of learning in natural environments. Semken and Freeman [21] reported significant pre–post gains in place attachment and place meaning in a small Arizona-based geology course, while explicitly cautioning that the small, self-selected sample and absence of a control group left alternative explanations open.

These findings do not mean that every local phenomenon automatically improves learning. Harris et al. [5] found that teachers could add locally relevant phenomena to storyline units, but their 12-teacher study also showed that teachers' knowledge of local resources and confidence in interpreting them mattered. The authors noted that their data did not fully

capture the range of resources teachers used or which design and professional-learning features supported adaptation. Accordingly, the framework treats local relevance as a design task requiring teacher preparation, community consultation, and scientific checking—not simply as inserting a place name into a lesson.

Local wisdom can be introduced as a source of questions, practices, historical observations, and interpretations. It should be attributed to its holders, contextualised, and compared with other evidence. A community's account of seasonal change, for example, may help children identify a pattern worth investigating; measurements of rainfall, temperature, water level, or species occurrence can then support or complicate that account. The purpose is neither to dismiss local knowledge nor to declare it scientifically confirmed in advance. Rather, the purpose is to create a respectful dialogue between knowledge traditions and evidence.

B. Narrative framing and scientific meaning

The second component uses a narrative to organise a phenomenon around a meaningful question or problem. A story may introduce a character, a community concern, a change over time, conflicting explanations, or a decision that depends on evidence. Its pedagogical role is to make the question memorable and consequential while leaving the scientific explanation open to investigation.

Oberman [15] identified picturebooks as serving different functions in inquiry-based education, including invitations, provocations, mentors, models, touchstones, resources, and destinations. This suggests that a storybook can launch an investigation or help learners revisit a question, rather than merely deliver facts. Freitas et al. [3] showed through qualitative multimodal analysis that ocean-themed picturebooks can represent scientific content, local marine awareness, positive attitudes toward science, and women scientists. Such analysis supports the potential of carefully selected texts, but it does not by itself show how much children learn after reading them.

The need for caution is reinforced by Soares et al. [23], whose theoretical review of 36 studies found inconsistent results for narrative and science learning. Narrative is not always more effective than expository presentation, and the learning activity around a text matters. Norris et al. [14] likewise developed a theoretical account of narrative explanation while emphasising that narrative has limits: science also depends on cautious description, argument, replicable methods, and critical evaluation. In the proposed framework, the story therefore provides a reason to inquire; it does not predetermine the answer or replace evidence-based explanation.

The environmental picturebook literature adds a further ethical criterion. Knauf [11] found that environmental and climate nonfiction picturebooks often connect scientific information to children's experience but can assign responsibility to children and families in normative

ways. Rybak [19] observed that action-oriented picturebooks may offer practical actions yet sometimes promote idealised or inaccessible solutions with limited critical reflection. Eco-storytelling should therefore avoid making children feel solely responsible for structural problems such as industrial pollution, infrastructure failures, or climate change. It should distinguish actions children can realistically take from responsibilities that belong to adults, institutions, and governments.

C. Evidence-generating inquiry

The third component is a transition from story to investigation. Children identify what needs to be explained, pose questions, plan observations or simple tests, collect data, compare patterns, and use evidence to revise an initial account. The exact inquiry method depends on the phenomenon and age group; a local issue need not always require an outdoor field trip. Photographs, maps, samples, classroom models, public data, or a short observation routine may be appropriate where access, safety, or time is limited.

Research on phenomenon-based learning and storylines provides a relevant design context. Harris et al. [5] describe how teachers adapt phenomena in elementary storyline units. Walker and Nouri's [24] systematic review of 24 studies of phenomenon-based learning and storylines identifies themes involving theory, curriculum design, teacher development, student learning, context, and implementation challenges. Jiménez-Valverde [9] likewise distinguishes historical narratives, realistic fiction, and science fiction or fantasy, while emphasising the need for empirical work that balances narrative appeal with scientific accuracy. These reviews establish that narrative-centred science design is an active research area, not that any one sequence is universally effective.

A key design principle is to preserve a visible boundary between the story's fictional elements and the empirical phenomenon. Characters can ask questions or represent viewpoints, but students should know which statements are fictional, which are community accounts, which are observations, and which are scientific explanations supported by data. The teacher can explicitly model the difference between a claim, evidence, and reasoning. A story's resolution should be open to the evidence rather than guaranteed by the author's preferred moral.

The key analytical output is a distinction among three narrative functions: initiating attention, sustaining a question over time, and communicating an evidence-supported explanation. These functions need not be carried by the same text. A fictional character might provoke the question, while photographs, measurements, interviews, and scientific diagrams provide evidence for answering it. Project-based science learning reinforces the importance of sustained disciplinary work rather than a sequence of appealing activities without an explanatory purpose [31].

D. Explicit numeracy

The fourth component deliberately incorporates quantitative reasoning where it fits the phenomenon. Learners may count litter items by category, measure plant growth, compare shade temperatures, record rainfall, tally pollinator visits, estimate water use, or map the distribution of observations. They can organise data in tables, draw simple graphs, compare quantities, describe trends, and discuss uncertainty. These activities connect mathematics to scientific questions and give children a reason to interpret numbers rather than simply complete a worksheet.

However, the reviewed corpus does not establish that eco-storytelling as an integrated approach improves numeracy. [1] coded science learning and mathematical concepts within the broader cognitive-development category in early-childhood environmental education, but the review's scope was not a test of an eco-storytelling numeracy intervention. [4] discuss questionnaires, tests, and formative assessment tasks in place-based science, but their review explicitly does not make general claims about efficacy. Consequently, numeracy is included here as a planned design component whose learning outcomes must be measured in future studies.

A useful planning rule is to state the quantitative action before designing the story: What will children count, measure, compare, classify, represent, or infer? If the phenomenon offers no meaningful quantitative question, numeracy should not be forced into the narrative. Conversely, if children gather data but never interpret or discuss it, the numerical activity risks becoming decorative. A later assessment should separately examine data collection accuracy, representation, interpretation, and use of quantitative evidence in an explanation.

E. Environmental agency

The fifth component connects understanding with realistic action and reflection. [17] offer direct but context-specific evidence: children in workshops about bee decline encountered a story, dance, and practical activities that modelled achievable actions such as supporting wildflowers. Survey and discussion data indicated enthusiasm, perceived agency, and intentions to act. The authors also caution that the resources used in the workshop—a professional dance production and purchased materials—were specific to their context, so they provide a simplified design guide rather than a one-size-fits-all intervention.

The value–action gap literature cautions against assuming that knowledge or positive attitudes will naturally lead to behaviour. [16] reviewed education research across multiple disciplines and identified both pedagogical and policy-oriented approaches, emphasising that education operates alongside other influences. The review questions simplistic models in which knowledge, attitudes, and behaviour follow in a straightforward sequence. An

ecostorytelling framework should therefore make action pathways explicit and feasible, while also recognising material, social, cultural, and institutional constraints.

Simms and Shanahan [22] found that environmental identity in a sixth-grade school-science context involved multiple dimensions, including action with peers, awareness of threats, emotional responses, self-recognition, agency, changed behaviour across contexts, social recognition, and personal meaning. Their qualitative study included 35 students, interviews, and reflective journals, but they acknowledge that it captured one social context over a relatively short period and had limited information about students' prior identities and structural barriers. The study supports reflective attention to meaning and identity; it does not prove that a short story sequence creates durable environmental identity.

Häggström [7] explored a six-week storyline approach in two primary classes, using video observations in a sustainability education context. The storyline involved pupils escaping by boat, finding an island, building a sustainable society, and responding to an oil spill. The study foregrounds dialogue, relational care, collaboration, and reflection as possible supports for pupil agency. It remains a context-specific action-research study, so its insights should inform design rather than be generalised as universal effects.

Agency in this framework is not defined as asking children to solve environmental crises independently. It includes the capacity to ask questions, contribute evidence, deliberate with peers, identify feasible actions, communicate findings, and recognise when larger decisions are required from adults or institutions. Reflection asks learners what their evidence changed in their thinking, what action is possible, who else needs to be involved, and what barriers remain.

The relationship among the five constructs is therefore complementary rather than additive. A local phenomenon gives the lesson ecological and social significance; local wisdom offers situated observations, practices, and questions that must remain open to respectful comparison with scientific evidence. Narrative links these elements through a question or decision, but it should not determine the answer in advance. Scientific literacy is foregrounded when pupils evaluate sources, interpret observations, construct explanations, and justify claims. Numeracy becomes part of that reasoning when pupils select and interpret counts, measurements, comparisons, tables, or graphs that are genuinely relevant to the phenomenon. Reflection then asks how evidence, values, uncertainty, and different community interests affect possible responses. In this account, environmental agency is a possible educational outcome to investigate—not an automatic consequence of understanding a story or caring about nature. The proposed framework's distinctive contribution lies in making these relationships visible in a single design sequence and in specifying where teachers should collect evidence of learning.

F. Integrated framework

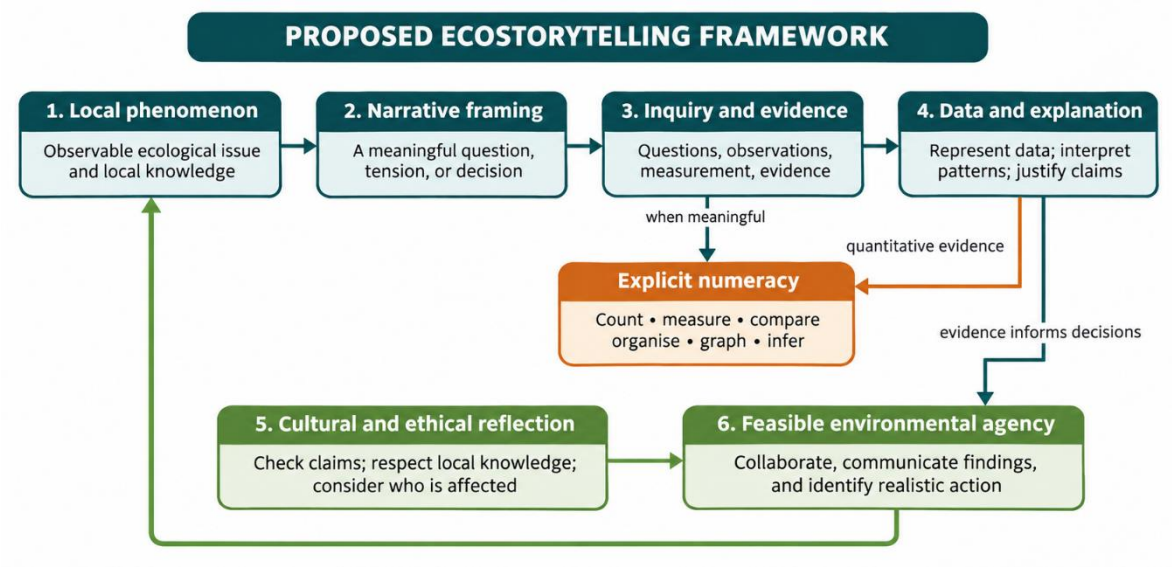


Fig. 1. Proposed ecostorytelling framework linking local ecology, narrative, inquiry, numeracy, reflection, and environmental agency.

The synthesis yields a six-part sequence. The sequence is intended to guide design, not to prescribe a rigid lesson script.

1. Local phenomenon and knowledge map. Select an observable ecological phenomenon; identify local knowledge holders, curricular goals, safety/access constraints, and relevant scientific concepts.
2. Narrative framing. Construct a concise, age-appropriate story around a genuine question, tension, or decision. Keep fiction distinguishable from evidence and avoid crisis-only narratives.
3. Inquiry question and evidence plan. Translate the story problem into a question children can investigate. Decide what observations, measurements, sources, or comparisons could support an answer.
4. Data and explanation. Collect and represent evidence; make numeracy explicit where meaningful; compare explanations and discuss uncertainty.
5. Cultural and ethical reflection. Consider local knowledge respectfully, check scientific claims, discuss who is affected, and distinguish child-level actions from systemic responsibilities.
6. Feasible agency and review. Choose an achievable action or communication product, collaborate with relevant adults/community partners, and reflect on evidence, agency, limitations, and next questions.

The six parts are interdependent. Local context supplies relevance but needs scientific checking. Narrative supplies coherence but must not dictate the conclusion. Inquiry supplies evidence but needs interpretation. Numeracy supplies tools for reasoning but must be aligned

to the question. Reflection supplies ethical and cultural perspective but must not romanticise local knowledge. Action supplies a possible pathway to agency but must be feasible and must not substitute individual behaviour for institutional responsibility.

The framework is best understood as an instructional design cycle rather than a causal pathway. Revision is possible at each phase: unexpected observations may alter a narrative explanation, community feedback may change an action plan, and an unanswerable question may require a different source of data. Teachers should record such deviations because successful adaptation is part of the framework, not necessarily a failure of implementation.

G. Propositions suitable for empirical testing

The framework yields five testable propositions. First, compared with a story-only lesson, a story-to-inquiry sequence should produce stronger evidence use in students' explanations if the inquiry is explicit and appropriately scaffolded. Second, explicitly planned measurement and data representation should yield clearer gains in targeted numeracy skills than an otherwise similar sequence where numbers appear only incidentally. Third, narratives that model feasible collective action may support perceived agency and action intentions more reliably than crisis-focused narratives without an action pathway. Fourth, teacher preparation and community asset mapping may affect the quality and cultural responsiveness of local phenomenon selection. Fifth, effects may differ by prior knowledge, access to local environments, reading comprehension, language, and sense of place.

These propositions are hypotheses for future study, not conclusions established by the present synthesis. A future design-based study could iteratively co-design units with teachers and community members, document adaptations, and test the framework with a transparent comparison condition. Measures should separate science conceptual understanding, quality of evidence-based explanation, specific numeracy competencies, perceived agency, and observed or reported action. Follow-up measurement is needed before making claims about durability. Qualitative interviews and student work could explain how learners interpret narrative, local knowledge, and data.

Discussion

A. Contribution to science education theory

The synthesis connects several strands that have typically been discussed separately. Situated learning clarifies why participation in meaningful local practices can matter for understanding, although proximity to a familiar setting does not itself ensure conceptual change [35]. Sociocultural accounts of learning draw attention to dialogue, scaffolding, and shared interpretive tools [34]. Within the proposed framework, these ideas are translated into teacher-guided movement between everyday accounts and defensible scientific claims. The

local setting is therefore a problem-generating resource, while disciplinary investigation remains the mechanism through which a learner can question, refine, or reject an explanation.

Environmental agency is more demanding than exposure to a persuasive conservation story. Jensen and Schnack differentiate action competence from mere behaviour modification or isolated activity [26]. This distinction matters in a primary classroom, where children may be able to collect and communicate evidence but cannot independently determine municipal waste services, water infrastructure, or land management. The educational target is the capacity to participate intelligently and collectively in a relevant decision, not compliance with a fixed list of individual behaviours.

Similarly, scientific literacy for citizenship involves assessing how claims are warranted, identifying the limits of evidence, and considering values in socioscientific decisions [28], [29]. This strengthens the rationale for a reflective phase after inquiry. Learners might conclude that water measurements show a problem while also recognising uncertainty about its source, conflicting community needs, and the need for decisions by responsible authorities. Such critical judgment should be valued even when no immediate environmental improvement follows.

B. Pedagogical implications and assessment

Teachers can begin with a short local observation rather than a fully produced storybook. A photo of a blocked drain after rain, a school garden with different growth rates, or a local stream with changing water levels can frame a question. Students can suggest explanations, identify what evidence would help, and gather a small set of observations. The teacher can then introduce a story, character, or community perspective that helps learners see why the question matters. The narrative should remain brief enough to leave time for scientific work.

Planning should align curriculum, story, data, and assessment. A teacher planning a waste-related story, for example, might define a target concept (material decomposition or ecosystem impact), a numeracy target (classifying and graphing waste by type), and an explanation target (using data to justify a claim). The action might be a school-level audit or a recommendation to school management, not simply a demand that children stop using plastic. A water-related story might combine local accounts of seasonal change with measurement of rainfall or water use, while recognising that access to safe water can depend on infrastructure beyond pupils' control.

Teachers should also use inclusive and low-cost options. If field access is unsafe or unavailable, the inquiry can use photographs, classroom specimens, public datasets, or school-ground observations. Children should be able to participate through drawing, oral discussion, measurement, writing, and collaborative tasks. A narrative can be fictional or nonfiction, but scientific accuracy and the boundary between story and evidence should remain explicit.

Teachers should document whose local knowledge was represented and invite correction from community knowledge holders when appropriate.

Assessment should avoid combining distinct outcomes into a single uninformative engagement score. Scientific understanding can be evaluated through concept questions and explanation tasks; inquiry competence through the quality of questions, evidence selection, and justification; numeracy through accuracy of representation and interpretation; and agency through indicators of perceived efficacy, collaborative deliberation, communication, and appropriately documented action. These dimensions should be reported separately, because strengths in one domain do not establish learning in another. The OECD PISA 2025 science framework distinguishes explanation, inquiry and evidence evaluation, and using scientific information for decision-making and action, thereby reinforcing the importance of outcome differentiation [33].

Multimodal story resources also warrant design restraint. Mayer's account of multimedia learning suggests that the selection and coordination of verbal and visual representations should serve comprehension rather than visual novelty [32]. For instance, a photograph of a local river and an annotated data table can be more useful than a highly illustrated fictional scene if the intended outcome is comparison of water levels. Accessibility also requires oral versions, text alternatives, uncluttered figures, and options for collaborative participation.

C. Contradictory evidence and boundaries

Several sources limit a simple positive account of storytelling. [23] found inconsistent evidence for narrative benefits in science learning. Norris et al. [14] argue that narrative has limited usefulness where science requires generality, precise description, and critical argumentation. Rybak [19] shows that action-oriented picturebooks can offer idealised solutions with limited critical engagement. Portus et al. [16] challenge the assumption that environmental knowledge and values automatically translate into action. These findings do not invalidate the framework; they specify design safeguards: narrative must be paired with inquiry and argument, action must be feasible and contextualised, and outcomes must be measured rather than presumed.

Other evidence also calls for caution about generalisation. Ge et al. [4] note that the place-based science literature is dominated by Western settings and that their review did not explicitly assess study effectiveness. Ardoin and Bowers [1] were limited to English-language empirical studies of children aged birth to eight and identified geographical gaps. Simms and Shanahan [22], Junker et al. [10], and Harris et al. [5] each describe context- or sample-specific constraints. These limitations matter for an Indonesian primary-school application: local ecological phenomena and wisdom should be developed with local stakeholders rather than

imported from examples involving bees in England, marine environments in Australia, or geology in Arizona.

Several alternative explanations must be considered in subsequent evaluations. Gains observed during a story-rich unit could result from extra instructional time, teacher enthusiasm, novelty, outdoor access, additional measurement practice, or more opportunities to discuss explanations. Comparison groups should therefore be matched as closely as practical on duration, curricular objectives, and opportunity to investigate. Pre-specified outcome definitions and delayed follow-up would help distinguish immediate engagement from durable competence and action.

D. Implementation and future testing

A feasible evaluation programme would begin with co-design among classroom teachers, science educators, and relevant community members. Small formative cycles could document conceptual accuracy, pupils' comprehension of the narrative, practical safety, accessible data-collection procedures, and alignment with curriculum goals. A later comparative study could evaluate the integrated sequence against a curriculum-equivalent condition, with unit of allocation, baseline differences, and classroom clustering explicitly addressed. If random allocation were not feasible, researchers should report the limitations of observational comparisons and avoid causal claims beyond the design.

Implementation fidelity should be conceptualised as fidelity to functions rather than identical lesson scripts. Important functions include posing an investigable problem, gathering evidence, interpreting quantities when relevant, examining cultural or ethical dimensions, and considering feasible action. Teachers should be able to substitute a school-garden investigation for a river survey when circumstances require it. Documentation should distinguish intended adaptation from omission of a core mechanism.

Conclusions

This conceptual synthesis proposes an ecostorytelling framework for primary science education that connects a locally meaningful ecological phenomenon with narrative framing, evidence-generating inquiry, explicit quantitative reasoning, cultural and ethical reflection, and feasible environmental agency. The reviewed literature supports the relevance of place, experiential learning, narrative as a resource for inquiry, and opportunities for children to reflect and act. At the same time, the evidence is mixed: narrative does not invariably outperform expository text, environmental awareness does not guarantee action, and many studies are context-specific or do not measure literacy and numeracy directly. The framework should therefore be treated as a testable design proposition, not as a proven intervention. In practice, teachers should select phenomena that children can investigate, preserve the distinction between story and evidence, make numerical reasoning explicit when it serves the

question, consult local knowledge holders respectfully, and avoid assigning children responsibility for systemic environmental problems. Future research should co-design and iteratively test units in diverse primary-school settings, use separate measures of science understanding, evidence-based explanation, numeracy, agency, and action, and include follow-up assessment. Such work can establish whether and under what conditions the proposed integration is useful, for whom, and with what limitations.

The immediate research priority is not to assert a universal learning advantage but to specify what the six phases accomplish and test their contribution in diverse classrooms. The framework offers a coherent route from situated ecological questions to inquiry, numerical interpretation, reflective dialogue, and responsible participation, subject to empirical validation and appropriate local adaptation.

Conflict of Interest

The authors declare no conflict of interest.

References

[1] N. M. Ardoin and A. W. Bowers, "Early childhood environmental education: A systematic review of the research literature," *Educational Research Review*, vol. 31, Art. no. 100353, 2020, doi: 10.1016/j.edurev.2020.100353.

[2] R. Ballantyne and J. Packer, "Introducing a fifth pedagogy: Experience-based strategies for facilitating learning in natural environments," *Environmental Education Research*, vol. 15, no. 2, pp. 243–262, 2009, doi: 10.1080/13504620802711282.

[3] C. Freitas, P. Francis, A. Bellgrove, and P. Venzo, "Adopting ocean-themed picture books to promote ocean literacy in primary education," *Children's Literature in Education*, vol. 55, pp. 701–716, 2024, doi: 10.1007/s10583-023-09534-y.

[4] J. Ge, J. Cheng, X. Liang, and J. Zhang, "Place-based learning in K-12 science education: A systematic review," *Educational Research Review*, vol. 52, Art. no. 100826, 2026, doi: 10.1016/j.edurev.2026.100826.

[5] E. M. Harris, L. Mohan, A. A. Hanson, K. A. Cook Whitt, C. Guy-Gaytán, and L. O. Kenyon, "'Adapting for a local space can be tricky': Designing units for teachers to localize through phenomenon adaptation," *Science Education*, vol. 109, no. 6, pp. 1551–1582, 2025, doi: 10.1002/sce.21978.

[6] R. T. Helsel, S. Lambert, L. Dickerson, J. Strelich, V. Woods, and D. Feldwinn, "Design of a phenomenon-based science outreach program and its effects on elementary students' epistemological understanding of, and attitudes toward, science," *School Science and Mathematics*, vol. 122, no. 2, pp. 74–85, 2022, doi: 10.1111/ssm.12515.

[7] M. Häggström, "Utilizing a storyline approach to facilitating pupils' agency in primary school sustainability education context," *The Journal of Environmental Education*, vol. 53, no. 3, pp. 154–169, 2022, doi: 10.1080/00958964.2022.2067110.

[8] P. Högström, N. Gericke, J. Wallin, and E. Bergman, "Teaching socioscientific issues: A systematic review," *Science & Education*, vol. 34, pp. 3079–3122, 2025, doi: 10.1007/s11191-024-00542-y.

[9] G. Jiménez-Valverde, "Narrative approaches in science education: From conceptual understanding to applications in chemistry and gamification," *Encyclopedia*, vol. 5, no. 3, Art. no. 116, 2025, doi: 10.3390/encyclopedia5030116.

[10] M. Junker, K. Hobson, W. Poortinga, J. P. Reeves, J. Newth, M. Stead, M. Marshall, and M. Gattis, "Pathways to nature connection? A photo-elicitation exploration on how children engage with a nature connection programme," *Environmental Education Research*, vol. 32, no. 6, pp. 1697–1725, 2026, doi: 10.1080/13504622.2025.2600603.

[11] H. Knauf, "Between knowledge and action: A qualitative study of children's non-fiction picture books on the environment and climate," *Zeitschrift für Didaktik der Naturwissenschaften*, vol. 29, Art. no. 4, 2023, doi: 10.1007/s40573-023-00152-1.

[12] D. M. McKnight, "Overcoming 'ecophobia': Fostering environmental empathy through narrative in children's science literature," *Frontiers in Ecology and the Environment*, vol. 8, no. 6, pp. e10–e15, 2010, doi: 10.1890/100041.
[13] National Research Council, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC, USA: National Academies Press, 2012, doi: 10.17226/13165.
[14] S. P. Norris, S. M. Guilbert, M. L. Smith, S. Hakimelahi, and L. M. Phillips, "A theoretical framework for narrative explanation in science," *Science Education*, vol. 89, no. 4, pp. 535–563, 2005, doi: 10.1002/sce.20063.
[15] R. Oberman, "From invitation to destination: A systematic literature review of the use of picturebooks in inquiry-based education," *British Educational Research Journal*, vol. 49, no. 3, pp. 555–574, 2023, doi: 10.1002/berj.3856.
[16] R. Portus, E. Aarnio-Linnanvuori, B. Dillon, F. Fahy, D. Gopinath, A. Mansikka-Aho, S.-J. Williams, K. Reilly, and L. McEwen, "Exploring the environmental value action gap in education research: A semi-systematic literature review," *Environmental Education Research*, vol. 30, no. 6, pp. 833–863, 2024, doi: 10.1080/13504622.2024.2314060.
[17] R. Portus, S.-J. Williams, E. Peklanska, R. Portus, and T. Walmsley, "Buzzing about bees: Exploring action-based storytelling as a tool for children's environmental engagement and agency," *Environmental Education Research*, vol. 31, no. 5, pp. 1048–1068, 2025, doi: 10.1080/13504622.2025.2478430.
[18] A. L. Powers, "An evaluation of four place-based education programs," *The Journal of Environmental Education*, vol. 35, no. 4, pp. 17–32, 2004, doi: 10.3200/JOEE.35.4.17-32.
[19] J. Rybak, "Towards a literature of actions: Green informational picturebooks and critical engagement with fighting climate change," *Children's Literature in Education*, vol. 56, pp. 210–224, 2025, doi: 10.1007/s10583-023-09549-5.
[20] H. H. Scherer and A. P. Azano, "Storying the FEW nexus: A framework for cultivating place-based integrated STEM education in rural schools," *Education Sciences*, vol. 15, no. 6, Art. no. 744, 2025, doi: 10.3390/educsci15060744.
[21] S. Semken and C. B. Freeman, "Sense of place in the practice and assessment of place-based science teaching," *Science Education*, vol. 92, no. 6, pp. 1042–1057, 2008, doi: 10.1002/sce.20279.
[22] W. Simms and M.-C. Shanahan, "Qualitatively recognizing the dimensions of student environmental identity development within the classroom context," *Journal of Research in Science Teaching*, vol. 61, no. 1, pp. 3–37, 2024, doi: 10.1002/tea.21863.
[23] S. Soares, M. Gonçalves, R. Jerónimo, and R. Kolinsky, "Narrating science: Can it benefit science learning, and how? A theoretical review," *Journal of Research in Science Teaching*, vol. 60, no. 9, pp. 2042–2075, 2023, doi: 10.1002/tea.21851.
[24] K. Walker and N. Nouri, "Phenomenon-based learning and storylines in K-12 science education: A systematic review of current research, implementation, and future directions," *Frontiers in Education*, vol. 10, Art. no. 1648234, 2025, doi: 10.3389/feduc.2025.1648234.
[25] X. Zhang, W. Jung, and M. Asari, "Systematic review of environmental education teaching practices in schools: Trends and gaps (2015–2024)," *Sustainability*, vol. 17, no. 19, Art. no. 8561, 2025, doi: 10.3390/su17198561.
[26] B. B. Jensen and K. Schnack, "The action competence approach in environmental education," *Environmental Education Research*, vol. 3, no. 2, pp. 163–178, 1997, doi: 10.1080/1350462970030205.
[27] D. A. Gruenewald, "Foundations of place: A multidisciplinary framework for place-conscious education," *American Educational Research Journal*, vol. 40, no. 3, pp. 619–654, 2003, doi: 10.3102/00028312040003619.
[28] D. L. Zeidler, T. D. Sadler, M. L. Simmons, and E. V. Howes, "Beyond STS: A research-based framework for socioscientific issues education," *Science Education*, vol. 89, no. 3, pp. 357–377, 2005, doi: 10.1002/sce.20048.
[29] S. D. Kolstø, "Scientific literacy for citizenship: Tools for dealing with the science dimension of controversial socioscientific issues," *Science Education*, vol. 85, no. 3, pp. 291–310, 2001, doi: 10.1002/sce.1011.
[30] V. Braun and V. Clarke, "Using thematic analysis in psychology," *Qualitative Research in Psychology*, vol. 3, no. 2, pp. 77–101, 2006, doi: 10.1191/1478088706qp063oa.
[31] J. S. Krajcik and N. Shin, "Project-based learning," in *The Cambridge Handbook of the Learning Sciences*, 2nd ed., R. K. Sawyer, Ed. Cambridge, UK: Cambridge University Press, 2014, pp. 275–297, doi: 10.1017/CBO9781139519526.018.

[32] R. E. Mayer, *Multimedia Learning*, 2nd ed. Cambridge, UK: Cambridge University Press, 2009, doi: 10.1017/CBO9780511811678.
[33] Organisation for Economic Co-operation and Development, "PISA 2025 science framework," OECD, 2025. [Online]. Available: https://pisa-framework.oecd.org/science-2025/
[34] L. S. Vygotsky, *Mind in Society: The Development of Higher Psychological Processes*. Cambridge, MA, USA: Harvard University Press, 1978.
[35] J. Lave and E. Wenger, *Situated Learning: Legitimate Peripheral Participation*. Cambridge, UK: Cambridge University Press, 1991.
[36] R. K. Yin, *Case Study Research and Applications: Design and Methods*, 6th ed. Thousand Oaks, CA, USA: SAGE Publications, 2018.
[37] J. W. Creswell and C. N. Poth, *Qualitative Inquiry and Research Design: Choosing Among Five Approaches*, 4th ed. Thousand Oaks, CA, USA: SAGE Publications, 2018.

Authors



Erika Fitri Wardani, M.Pd. is an academic at Universitas Muhammadiyah Bangka Belitung, Indonesia, specializing in education and biology. Her research focuses on innovative teaching approaches, instructional media, and student learning outcomes, particularly in elementary science and social science education (IPAS). She is committed to improving educational quality through interactive, technology-enhanced, and student-centered learning practices. (email: erika.fitriwardani@unmuhbabel.ac.id).



Dr. Ika Maryani, M.Pd. is an Associate Professor at the Department of Doctoral Program in Education, Faculty of Teacher Training and Education, Universitas Ahmad Dahlan (UAD), Yogyakarta, Indonesia. In 2022, she obtained her doctoral degree in educational studies, focusing on science education. Her research interests lie in teacher education, science education, higher education, and learning innovation. Her works have been published in books, articles, and proceedings at national and international levels. (email: ika.maryani@pgsd.uad.ac.id).



Dr. Asyraf Suryadin, M.Pd is senior academic in Indonesian language education, research methodology, and educational evaluation. He teaches Indonesian Language, Learning Evaluation, Research Methodology, Classroom Action Research, and Scientific Writing. His publications include *Bahasa Indonesia, Membaca dan Menulis* (2007) and *Penelitian Tindakan Kelas* (2012). His academic interests focus on literacy development and research capacity. (email: asyraf.suryadin@stkipmbb.ac.id).