

DEVELOPMENT OF SCIENCE TEACHING MATERIALS ON CHANGES IN THE STATE OF MATTER TO REMEDIATE MISCONCEPTIONS IN ELEMENTARY SCHOOL STUDENTS

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Article history:

Submitted: July 23rd, 2026; Revised: Aug. 20th, 2026; Accepted: Sept. 25th, 2026; Published: Oct. 29th, 2026

ABSTRACT

The material misconception of substance form change remains a systemic challenge in elementary schools due to conventional materials failing to visualize particle mechanics. This Research and Development (R&D) study aims to develop and test the theoretical feasibility of narrative-contextual story-based science materials, "Learning Park," to remediate misconceptions among grade III students. Using the ADDIE model limited to Analysis, Design, and Development stages, the product integrates peer adventures (Andi, Bagas, Tina), macro-micro particle models, and local coastal salt crystallization wisdom to trigger cognitive conflict. Scientific feasibility testing by 6 validators (3 UGJ expert lecturers and 3 SDN Mirat III teachers) showed the product met Very Feasible criteria with an average score of 89.84%, spanning material substance (89.58%), instructional design (87.50%), language readability (87.50%), evaluation synergy (89.58%), and visual communication (94.44%). Qualitative revisions—including particle analogies, enlarged speech balloon font, and 35% reduced background opacity—were accommodated. However, this study is limited to expert judgment validation without field testing. Nevertheless, this teaching material is highly suitable as a companion medium for student cognition recovery.

Keywords: nature of science; socioscientific issues; transformative learning

INTRODUCTION

Education is the main pillar of the intellectual, spiritual, and character foundations of the nation (Fatton, 2025) (Siswadi, 2025). In elementary school, science learning plays a crucial role in internalizing basic scientific concepts (Abdullah, 2022). in accordance with Law No. 20 of 2003 Article 3 to stimulate critical thinking (Fatmawati & Jaya, 2025). strengthened by Permendikbudristek No. 5 of 2022 Graduate Competency Standards (SKL) (Hidayat & Nurlatifah, 2023) and No. 7 of 2022 related to science literacy (Purnawati & Yakin, 2025). Science learning should ideally be interactive, fun, and motivate students' independence (Adawiyah et al., 2025).

Science is a way of thinking, investigating, and a body of knowledge (Rasyidi et al., 2022). that links natural phenomena to everyday life (Putrayasa et al., 2026). Students need to build an empirical evidence-based understanding (Khoiriyah & Fatonah, 2024). to solve problems and prevent logical errors (Farhin et al., 2023).

However, a critical educational gap persists. Learning remains dominated by rigid, teacher-centered verbalism (May et al., 2026). exacerbated by media limitations and heavy reliance on abstract textbooks (Fernanta et al., 2026). This directly contradicts the needs of elementary students in the concrete operational phase, who require visual representations to grasp

microscopic phenomena (Karimah et al., 2025). (Wulandari et al., 2026). Consequently, student misconceptions—characterized by systemic errors in terminology and concept classification—become deeply entrenched (Ngurah et al., 2016) (Suharto, 2022). particularly regarding the states of matter and their changes (Qatrunnada et al., 2025). Although Grade III curricula cover solids, liquids, gases, and six fundamental phase transitions (Mukminin et al., 2025). learners frequently rely on erroneous intuitive preconceptions.

Crucially, existing R&D studies from 2020 to 2026 exhibit two major blind spots. Conceptually, while recent literature focuses heavily on expert-validated instructional media, high expert judgment scores ($\geq 85\%$) merely establish theoretical feasibility; they provide zero quantitative or empirical proof of cognitive conflict execution or actual misconception remediation in classroom environments. Quantitatively, the field lacks empirical effect-size metrics (such as *N*-gain or diagnostic certainty indices) demonstrating that narrative-contextual models can measurably shift student mental models from misconceptual to scientific states. Validating materials through expert consensus alone leaves the actual effectiveness of particle-visualization tools unproven at the cognitive level.

Theoretically, to understand these changes in form holistically, students must be introduced to the mechanical characteristics of each form through its particle-level representation; How solids have particles that are tightly arranged and neatly (solid), liquids that begin to stretch and can shift (liquid), to gaseous substances that stretch freely without strong bonds (gases) (Nisa et al., 2026). It is these

microscopic characteristics that often fail to be visualized in conventional package books, thus triggering structural errors in students' minds. 4

The root of the problem is the lack of specific remediation teaching materials that are not *corrective-remediative* (John, 2024). that facilitate cognitive (Kurniawat, 2026). Teachers often assume that memorizing definitions or examples equals conceptual understanding, whereas verbal memorization differs significantly from molecular-level understanding (Fahreza & Heryanto, 2024).

Elementary science education research from 2020–2026 has focused on mapping misconceptions based on cognitive conflict, but remains largely confined to evaluation without providing independent intervention media. While visual stories effectively increase children's science literacy in the concrete operational phase (Syahrinanda et al., 2025). they are predominantly linear-informative without addressing misconception traps or microscopic particle visualizations. Furthermore, corrective teaching devices are mainly designed for higher grades (V and VI) using textual module formats. A research gap exists in integrating contextual stories, macro-micro particle mechanics visualization, and local wisdom into printed teaching materials for grade III misconception remediation.

To address these challenges, this Research and Development (R&D) study develops narrative-contextual story-based science teaching materials with the following advantages: (1) storytelling using child characters to trigger cognitive conflicts; (2) microscopic visual representations of substance particles; and (3) reasoning evaluations based on local wisdom to independently remediate

misconceptions. The novelty of this research lies in the integration of triadic storytelling (featuring Andi, Bagas, and Tina), macro-micro particle visualization simplification, and the ethnoscience of salt crystallization into grade III science teaching materials. Unlike previous 2020–2026 studies that separated stories into rigid modules, this product merges them into an ecosystem that triggers cognitive conflict and independent concept reconstruction, simplifying abstract transitions (evaporating, sublimating, crystallization) through macroscopic and molecular pictorial phenomena.

Based on these gaps, the formulation of this research problem includes: (1) identifying the characteristics and forms of

misconceptions of grade III elementary school students in state-of-matter materials; (2) determining the procedure and feasibility level (validity and practicality) of narrative-contextual story-based teaching materials; and (3) examining the effectiveness of corrective-remedative teaching materials in remedying misconceptions and improving concept mastery. Through a cognitive remediation approach, this study applies three continuous strategies: cognitive conflict via daily triggers, microscopic analogue bridges (solid, liquid, gas particle visualizations), and contextualization of state-change phenomena based on ethnoscience.

METHOD

Research *Research and Development* (R&D) develops science teaching materials with narrative-contextual storytelling patterns to remediate misconceptions of grade III elementary school students (Siregar, 2023) (Afriani, 2025). The framework adopted is the ADDIE model (Rusdi et al., n.d.). which is limited to the initial three stages: Analysis (*Analysis*), Planning (*Design*), and Development (*Development*). This restriction is carried out so that the focus of research is centered on the creation of teaching material formulations with a level of scientific validity and absolute theoretical feasibility from experts and practitioners.

RESEARCH FLOW DIAGRAM

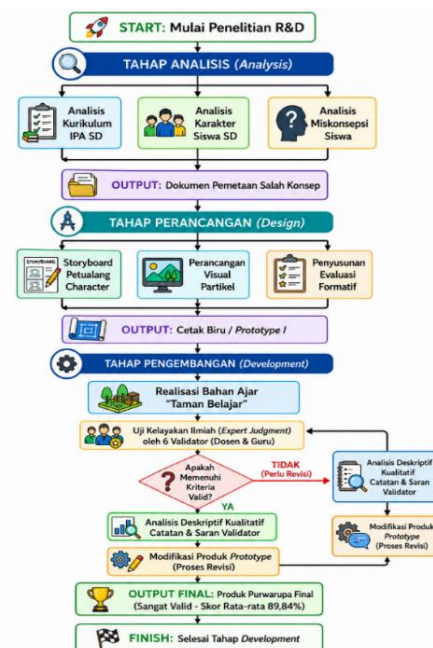


Figure 1. ADDIE Development Workflow (Limited to Development Stage) (Siregar, 2023)

This research procedure follows three main stages: **1. Analysis Stage:** Mapping the needs and diagnosing student

misconceptions through curriculum analysis of the form of substance in grade III elementary school, children's cognitive characteristics, and macro-micro misconceptions as a reference for constructing teaching materials. **2. Design Stage:** Compile a *blueprint* for "Learning Park", including the *storyboards* of Andi, Bagas, and Tina characters to trigger cognitive conflicts, particle visualization, remedial dialogue texts, and formative evaluations to produce *Prototype I*. **3. Development Stage:** Realizing physical products and conducting scientific feasibility tests (*expert judgment*) by material experts, media, and third grade elementary school teachers, followed by revision to produce a theoretically valid final product.

The Development phase translated the instructional designs into Prototype I and evaluated its theoretical validity through expert judgement. The expert judgment was conducted by 6 purposively selected validators based on specific professional criteria. The 3 expert lecturers from Universitas Swadaya Gunung Jati (UGJ) were selected for their doctoral/master's qualifications in Science Education and Elementary Pedagogy, backed by over five years of research experience in instructional design and cognitive remediation. Meanwhile, the 3 practitioner teachers from SDN Mirat III were chosen based on their S1 PGSD

degrees and a minimum of five years of teaching experience in Grade III classrooms, ensuring deep contextual familiarity with early-grade student misconceptions and curriculum implementation. The evaluation covered five main aspects: material substance, instructional design, language readability, evaluation synergy, and visual communication. Data were collected using structured validation questionnaires rated on a 4-point Likert scale (1 = Poor, 2 = Fair, 3 = Good, 4 = Very Good) along with qualitative feedback sheets. The quantitative validation data were analyzed using the percentage formula:

$$P = \frac{\sum x}{\sum x_i} \times 100\%$$

where P is the validation percentage, $\sum x$ is the total score assigned by validators, and $\sum x_i$ is the maximum total score. The resulting scores were categorized according to the validity criteria: Very Valid/Feasible (81.00% – 100.00%), Valid/Feasible (61.00% – 80.99%), Less Valid (41.00% – 60.99%), Invalid (21.00% – 40.99%), and Very Invalid (0.00% – 20.99%). Qualitative suggestions and revisions provided by the validators were descriptively analyzed to revise Prototype I into the final product (Prototype II).

RESULT AND DISCUSSION

The initial Analysis phase revealed critical diagnostic insights into Grade III science instruction under the *Kurikulum Merdeka* framework. Curriculum mapping showed that while Learning Outcomes (*Capaian Pembelajaran* / CP) require students to understand physical states and

thermal energy-driven state changes, students consistently experience structural misconceptions. Diagnostic findings indicated that students conceptualize evaporation as "matter vanishing into nothingness," condensation as "water leaking through solid glass," and

sublimation or crystallization as "spontaneous destruction or creation of matter." These misconceptions stem primarily from the inability of 3rd-grade concrete-operational learners to picture sub-microscopic particle dynamics. Furthermore, analysis of existing commercial textbooks highlighted a dependency on static verbal definitions, leaving a gap for corrective-remediative teaching media that bridge macroscopic observation with particle-level mechanics.

In response to these diagnostic findings and qualitative inputs from expert validators, the Design and Development phases systematically incorporated concrete structural and visual revisions into the teaching material. Pedagogically, the material establishes three core strategies: (1) a triadic narrative framework featuring peer characters (Andi, Bagas, and Tina) to provoke cognitive conflict and guide peer-led concept reconstruction; (2) age-appropriate macro-micro particle representations; and (3) the integration of local coastal salt crystallization ethnoscience to ground abstract chemical changes in familiar socio-cultural contexts.

Specifically, qualitative feedback directly reshaped the product content through targeted revisions:

- **Pedagogical Analogy Integration:** To prevent secondary misconceptions when simplifying particle mechanics for Grade III students, microscopic particle behaviors were revised into an intuitive "*children playing*" analogy—depicting solid particles as children holding hands tightly in place, liquid particles as holding hands loosely while moving, and gas particles as children running freely across an open space.
- **Visual and Typographic Optimization:** Based on visual

communication feedback, the font size inside character word balloons was enlarged to meet early-grade readability standards. Additionally, the opacity of background illustrations was reduced by up to 35% to eliminate visual clutter and increase text-to-background contrast, ensuring seamless reading comprehension.

1. Quantitative Data (Validator Feasibility Assessment)

In the Development phase, the physical prototype (Prototype I) underwent rigorous expert validation involving 6 validators (3 expert lecturers from Swadaya Gunung Jati University and 3 practitioner teachers from SDN Mirat III). Quantitative evaluation across five key aspects confirmed high theoretical validity, as summarized in Table 1.

Table 1: Expert Validation Results of the Developed Teaching Material

Evaluation Aspect	Total Score Obtained	Max. Poss. Score	Percentage (%)	Perception
Material Substance	86	96	89.58 %	Very Valid
Instructional Design	84	96	87.50 %	Very Valid
Language Readability	42	48	87.50 %	Very Valid
Evaluation Synergy	43	48	89.58 %	Very Valid
Visual Communication	68	72	94.44 %	Very Valid
Overall Average	323	360	89.84 %	Very Valid

Table 2: Qualitative Feedback from Experts and Subsequent Product Revisions

Validator / Aspect	Qualitative Notes & Suggestions	Revision Action Taken
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Material Expert	Particle spacing explanation needed a clearer concrete analogy for 3rd graders.	Incorporated the "children playing tag vs. holding hands" analogy to depict particle kinetic energy.
Instructional Expert	Word balloons in story panels were visually dense, impacting readability.	Enlarged word balloons by 15% and adjusted line spacing for readability.
Media/Visual Expert	Background opacity on narrative pages competed with foreground text legibility.	Reduced background graphic opacity by 35% to enhance text contrast.

The high validation result (89.84%) substantiates that merging narrative-contextual storytelling with microscopic particle visualization overcomes the limitations of abstract science textbooks. According to Piaget's theory of cognitive development, Grade III students remain in the concrete operational stage, requiring visual and narrative mediators to process abstract physical phenomena. By embedding state-change concepts within the adventures of Andi, Bagas, and Tina, the material creates intentional cognitive conflict—a critical catalyst for conceptual change. When learners encounter daily scenarios where their preconceptions fail to explain the characters' observations (such as salt formation or water drop condensation), they are prompted to reconstruct their mental models. Moreover, linking macroscopic phenomena with particle-level representations provides the

explanatory bridge necessary to eliminate persistent misconceptions, while the inclusion of local salt-making ethnoscience reinforces meaningful, contextual scientific literacy.

In addition to providing assessments in the form of numerical scores, the six validators provided descriptive notes to improve the prototype of teaching materials. Qualitative data is processed through an interactive model (data reduction and data presentation) and is classified into the following two main groups:

A. Academic Input of the Expert Lecturer Group:

- *Background Visual Control:* Suggest that the background visual effects on the panels containing crucial material be made somewhat blurry or transparent so that the cognitive focus of grade III students is not fragmented and the contrast of the writing is easy to read.
- *Textbook Completeness Structure:* Suggests adding completeness components in the form of material concept maps, Learning Objectives (TP) sheets, author profile/biography sections, text size improvements, foreword shrinkage, and spacing of the table of contents layout to be more proportional.
- *Representation of Titles with Plot:* Suggests that the spirit of the main title of the teaching material "Learning Park" is represented more strongly in the character's narrative adventures.
- *Molecular Conceptual Simplification:* Provides notes to refine the description of the language of science on microscopic particle diagrams (solid, liquid, gas) to make them more concrete and adaptive to the limits of reasoning of grade III students.

B. Practical Input for the Elementary School Teacher Group:

- *Narrative Approach*: Assessing the use of adventure plots of peer characters (Andi, Bagas, and Tina) is very effective in acting as a curative-remediative instrument as well as triggering children's interest in reading post-pandemic which tends to decline.
- *Wording Bubbles*: Reminds that the font size on the text bubble is made large, sharp, and uses colors that *match* the surrounding color combination.
- *Strengthening the Diagram & Evaluation Code*: Suggest that evaluation questions be made softer for grade III children and add text captions or clear distinguishing symbols to the modeling of the mechanics of substance particles so that students who study independently at home do not experience misinterpretations.

C. Discussion

The results of the quantitative feasibility test showed an average percentage of (Very Valid), proving that the science teaching materials "Learning Park" had met the standards of content, didactic, linguistic, and graphic validity for grade III elementary school. Theoretical and practical presentations are discussed through the following pillars of analysis: 89,84%

2. Qualitative Data (Validator Criticism & Improvement Suggestions

1. Visual Graphic Validity as a Cognitive Stimulus for Children Phase B

The Visual and Graphic Communication aspect obtained the highest score (100), in accordance with the cognitive characteristics of Phase B children (grade III of elementary school) at the concrete operational stage (Piaget) 94,44% (Busri et al., 2026). Its visual advantages include: distinctive expressions of the characters Andi, Bagas, and Tina to internalize cognitive conflict (*cognitive conflict*); linear word-balloon arrangement to prevent visual fatigue; as well as a perfectly valuable concrete particle diagram. Based on *Dual Coding Theory* (Paivio), integrating text and particle diagrams reduces cognitive load (*cognitive load*) so that the microscopic structure of the substance form is formed without triggering visual confusion.

2. Remediation of Misconceptions Through Conceptual Change Model

The validity of the material is as much as strengthening the position of this teaching material as a clinical intervention tool. Adopting the CCM syntax by Posner et al. 89,58% (Samsudin et al., 2024). Cognitive reconstruction facilitates four phases: *Dissatisfaction* (triggering dissatisfaction through the phenomenon of ice cream melting in a warm canteen); *Intelligibility* (introducing new concepts via visual comparison of tight vs loosened particles); *Plausibility* (Proving the truth of the concept

through the shrunken camphor and evaporated wet clothes); and *Fruitfulness* (strengthening the feasibility of the concept through the ethnoscience of coastal salt making/deposition).

3. The Application of the Triadic Representation (*Johnstone's Triplet*)

In order to overcome science learning that is often trapped in verbal and instant explanations, this teaching material integrates three levels of integrated representation based on *Johnstone's Triplet* (Wicaksono et al., 2022):

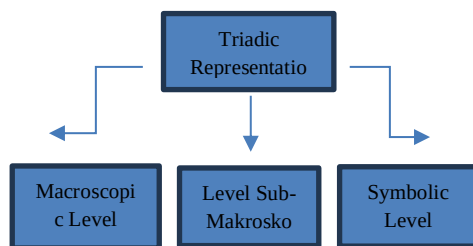


Figure. 2 *Johnstone's Triplet*
three levels

1. **Macroscopic Level:** through the visualization of real objects of everyday phenomena
2. **Sub-Microscopic Level:** presents modeling of particle mechanics via *zoom-in illustration* of molecular densities
3. **Symbolic Level:** in the form of visual code of particle coloring and heat energy transfer arrows (red for heat, blue for cold).

The collaboration of these three levels of representation

simultaneously helps students build a complete mental schema (*mental model*). When they see boiling water, students don't just memorize the word "evaporate," but understand the physical process when water particles absorb heat energy, loosen the bonds between molecules, and release themselves into free-floating gases.

4. Design Transformation Based on Expert Recommendations (*Design Refinement*)

The research at this *Development stage* is refined through conceptual and visual revisions based on constructive criticism by the validator team. The reconstruction of the draft of *Prototype I* into *Prototype II (Final)* is focused on improving *usability* and cognitive comfort of readers:

- **Molecular Particle Analog Simplification (V2 & V4 Input Response):**

The explanation of the intricate movement of particles is simplified into the analogy of "children playing": solid substances as "children lined up tightly and hand in hand", liquid substances as "children take off their grips but stay close together", and gases as "children running free on the field". This analogy successfully bridges abstract microscopic concepts into concrete for third-grade students.

- **Background Illustration Opacity Reduction (Input Response V1 & V4):** The researcher lowered the background opacity of the story panel by 35% in the core material dialogue section. This visual revision keeps the text contrast easy to read while preventing a *split-attention effect* (a split in students' concentration due to focusing more on decorative images than material text).
- **Labeling of Particle Diagrams and Word Balloon Font Sizes (Input Responses V5 & V6):** The researcher enlarged the font size of the dialogue balloon to a minimum of 12pt Comic Sans, thickened the word balloon divider, and included text caption labels on the image of the molecular representation. The addition of this label ensures that grade III students can understand the material correctly when learning independently at home without the assistance of a teacher.

5. Limitations of Research and Recommendations

CONCLUSION

Based on the results of research and development (R&D) with modification of the ADDIE model (limited to *the Analysis, Design, and Development stage*), the science teaching materials based on the story "Learning Park" were declared **Very Valid** and **Very Feasible** to remedy misconceptions of material changes in the form of substances in grade III elementary

Despite achieving very high feasibility, this R&D research has procedural limitations because it is limited to the 89,84% *Development* (ADD) stage without extensive implementation tests and impact evaluations. The reported validity is still limited to theoretical *validity* from the perspective of experts and practitioners.

Based on these limitations, recommendations for further research include:

1. **Empirical Trial:** Conducting a *quasi-experimental* experiment to measure the *empirical validity* of teaching materials on improving students' understanding and reducing misconceptions through *N-gain values*.
2. **Developing Interactive Digital:** Developing "Learning Gardens" teaching materials into an interactive digital format (such as a Webtoon or Android app) with *real-time motion* animation of molecular particles to strengthen sub-microscopic visualization

school. The theoretical validity of this final prototype was proven through an expert judgment test by 6 validators (3 UGJ expert lecturers and 3 practitioner teachers of SDN Mirat III) with an average eligibility score of 89.84% (Very Feasible). Its core advantage lies in integrating peer character storylines (Andi, Bagas, Tina), macro-micro particle mechanics visualizations, and local coastal salt ethnoscience to trigger cognitive conflict. Although limited to the

material validation stage without field trials, all expert inputs have been fully accommodated to produce a mature companion medium. **As a priority recommendation for future research**, a quasi-experimental study employing a pretest-posttest control group design should be conducted with a sample size of at least 60 Grade III students. Furthermore, future studies should utilize four-tier diagnostic instruments combined with a delayed post-test (4 weeks post-intervention) to empirically evaluate the remediation of misconceptions and long-term concept retention.

ACKNOWLEDGMENTS

The author expresses his highest respect and appreciation to Universitas Swadaya Gunung Jati (UGJ), especially the Elementary School Teacher Education Study Program (PGSD) for the support of academic facilitation, as well as to the Main Supervisor and Accompanying Supervisor who have provided guidance, clinical direction, and constructive criticism during the process of refining this research. Gratitude was also addressed to the UGJ Validator Expert Lecturer team, the Principal, as well as the Practitioner Teachers and third grade students of SDN Mirat III for the permission, cooperation, and objective assessment given in testing the feasibility and practicality of the "Learning Park" teaching materials.

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