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Development of Deep Learning-Based Digital Interactive Multimedia to Improve Elementary Students' Critical Thinking on Ecosystem Material

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Abstract: Elementary students' critical thinking skills are commonly reported as low under lecture-centered instruction with minimal use of interactive media, a condition also confirmed at the research site through preliminary observation showing limited use of higher-order reasoning tasks. This study aimed to develop a practical and effective deep learning-based digital interactive multimedia, RAJA MAKAN, to improve fifth-grade students' critical thinking on ecosystem material. The product was developed using the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation), a systematic and cyclical instructional design framework in which each phase produces an output that becomes the reference for the following phase, involving expert validation, formative revision, and a small-group and large-group trial with fifth-grade students. As supporting data to this development process, material and media expert validation reached 87.7% and 86.7% respectively, teacher and student practicality reached 98% and 93%, and classical mastery increased from 53.3% to 93.3%, with a high N-Gain of 0.72 and a significant Wilcoxon test result ($p = 0.000$). These findings indicate that RAJA MAKAN was successfully developed through a systematic ADDIE process, offering a detective-themed, problem-oriented narrative structure that distinguishes it from existing ecosystem media, which remain largely generic and rarely embed a deliberate critical-thinking framework.

Keywords: critical thinking, deep learning, digital interactive multimedia, ecosystem, elementary school.

Abstrak: *Keterampilan berpikir kritis siswa sekolah dasar kerap dilaporkan rendah pada pembelajaran yang berpusat pada ceramah dengan minim penggunaan media interaktif, kondisi yang juga dikonfirmasi di lokasi penelitian melalui observasi awal yang menunjukkan terbatasnya penggunaan tugas bernalar tingkat tinggi. Penelitian ini bertujuan mengembangkan multimedia interaktif digital berbasis deep learning bernama RAJA MAKAN yang praktis dan efektif untuk meningkatkan berpikir kritis siswa kelas V pada materi ekosistem. Produk dikembangkan menggunakan model ADDIE (Analysis, Design, Development, Implementation, dan Evaluation), sebuah kerangka desain pembelajaran yang sistematis dan siklikal, di mana setiap tahap menghasilkan luaran yang menjadi acuan bagi tahap berikutnya, melalui validasi ahli, revisi formatif, serta uji coba kelompok kecil dan kelompok besar pada siswa kelas V. Sebagai data pendukung proses pengembangan ini, validasi ahli materi dan media masing-masing mencapai 87,7% dan 86,7%, kepraktisan guru dan siswa mencapai 98% dan 93%, serta ketuntasan klasikal meningkat dari 53,3% menjadi 93,3%, dengan N-Gain tinggi sebesar 0,72 dan hasil uji Wilcoxon yang signifikan (p = 0,000). Temuan ini menunjukkan bahwa RAJA MAKAN berhasil dikembangkan melalui proses ADDIE yang sistematis, dengan menawarkan struktur narasi bertema detektif berorientasi masalah yang membedakannya dari media yang telah ada, yang umumnya masih bersifat generik dan jarang menyisipkan kerangka berpikir kritis secara langsung.*

Kata kunci: *berpikir kritis, deep learning, multimedia interaktif digital, ekosistem, sekolah dasar*

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1. INTRODUCTION

Critical thinking has become a key competency of the twenty-first century that every learner must possess to face the rapid acceleration of science and technology. This capacity involves analysis, evaluation, and reflective synthesis of information that underlies sound decision-making and complex problem-solving in daily life. The Merdeka Curriculum currently implemented in Indonesia places explicit emphasis on strengthening critical thinking through student-centered and project-based instruction (Ariani et al., 2023). Building this competency from the earliest years of schooling is expected to establish a strong cognitive foundation for a creative, solution-oriented, and adaptive generation. This orientation is consistent with the vision of the Pancasila Student Profile, in which critical thinking is positioned as a core competency that should be nurtured from the beginning of formal education (Indasah & Safitri, 2025). Elementary education therefore needs to be deliberately designed to encourage learners to explore, analyze, and resolve problems they encounter in their everyday surroundings.

Empirical evidence, however, indicates that the critical thinking skills of Indonesian elementary students generally remain at a low-to-moderate level. A recent study revealed that most elementary students are still unaccustomed to working on higher-order reasoning tasks and are more frequently exposed to rote memorization and factual recall exercises (Mahardika et al., 2025). This condition is compounded by teaching practices that remain repetitive and content-delivery oriented rather than idea-exploration oriented, leaving students with limited opportunity to practice posing critical questions, testing arguments, or connecting concepts to authentic contexts. Preliminary observation at SD Zainuddin Waru Sidoarjo confirmed that learning outcomes in Natural and Social Sciences (IPAS) remained below the minimum mastery criterion, were textbook-centered, and made minimal use of interactive media. National computer-based assessment data further showed that the critical evaluation component of literacy declined from a score of 54.74 in 2024 to 53.56 in 2025, a pattern consistent with international assessment findings that place Indonesian students' higher-order reasoning well below the OECD average (OECD, 2023). Such a gap between curricular aspiration and classroom reality signals an urgent need for pedagogical intervention specifically directed at ecosystem material, a topic conceptually close to students' lived experience yet frequently treated abstractly.

An instructional approach commonly proposed to close this gap is deep learning, in which students are pushed beyond memorization toward understanding, reflection, and the deliberate linking of concepts with practical experience (Fitriani et al., 2026). This approach requires learners to actively construct meaning through exploration, collaboration, and reflective problem-solving rather than passively receiving information from the teacher. Recent research on deep learning implementation in basic education confirms that instructional designs emphasizing active and reflective engagement are more effective at cultivating durable conceptual understanding than transmission-based instruction (Weng et al., 2023). Combining a deep learning orientation with an innovative delivery medium is therefore considered a promising strategy for addressing the persistently low critical thinking performance of elementary learners. This premise forms the pedagogical basis on which the present multimedia product was conceived and designed.

Alongside this pedagogical need, the rapid advancement of digital technology has opened considerable opportunity to design learning media that are more interactive, immersive, and contextually relevant. Interactive multimedia integrating animation, simulation, and reflective assessment has been shown to increase motivation, engagement, and critical thinking more effectively than lecture-dominated instruction (Andayani et al., 2025). Elementary students today are also increasingly familiar with digital devices, which have become an integral part of both their learning and social routines rather than merely tools for communication. Evidence from recent development studies further shows that interactive e-modules delivered through familiar digital platforms produce measurable gains in student learning outcomes when properly aligned with curriculum objectives (Alyusfitri et al., 2024). The convergence of accessible technology and a felt pedagogical need therefore creates a timely opportunity to design a contextual, ecosystem-based interactive multimedia grounded in the deep learning approach.

Despite this opportunity, prior studies on digital learning media development remain largely confined to improving material visualization and general learning motivation rather than deliberately cultivating critical thinking. One study, for example, focused solely on technology-based media without integrating any deep learning strategy into its design (Daniar & Sari, 2022). Another study emphasized visual interactivity but did not comprehensively evaluate its impact on students' critical thinking skills (Sastradewi, 2022). This pattern reveals a persistent research gap regarding interactive learning media that is deliberately framed within a deep learning structure to sharpen elementary students' critical thinking, particularly on ecosystem material (Nabila et al., 2025). The absence of such an integrated design indicates that a genuine gap continues to separate the theoretical promise of deep learning-based multimedia from its practical realization in primary science classrooms. This gap raises the central research question of how an interactive digital multimedia grounded in deep learning can be systematically developed, validated, and tested to enhance elementary students' critical thinking on ecosystem material.

Ecosystem material presents its own pedagogical challenge in elementary science instruction. The topic requires students to understand dynamic and often invisible relationships among biotic and abiotic components, such as food chains, food webs, and the impact of environmental disturbance, concepts that are difficult to grasp through static textbook illustration alone. Preliminary observation at SD Zainuddin Waru Sidoarjo indicated that ecosystem topics were commonly delivered through brief lectures and textbook reading, with limited use of concrete cases, simulation, or guided investigation that could help students connect ecological concepts to real environmental problems such as deforestation, pollution, or species decline. This condition is compounded by limited locally contextualized teaching resources, since available ecosystem media are largely generic and seldom link ecological content to problem-based or investigative activities that train students to question, analyze evidence, and evaluate the causes of ecosystem disturbance. Addressing this gap requires an interactive delivery format combined with a content structure that situates ecosystem concepts within an authentic, problem-oriented narrative capable of driving critical engagement.

Responding to this need, the present study developed a deep learning-based digital interactive multimedia named RAJA MAKAN (RAntai dan JAring MAKANan), designed to strengthen fifth-grade students' critical thinking on ecosystem content (Puspita et al., 2025). The product was constructed through a research and development methodology, beginning with design formulation, followed by expert validation, and concluded with a limited field trial. Through digital visual design, video simulation, reflective online assessment, and problem-exploration worksheets, RAJA MAKAN is intended to increase student engagement while systematically training higher-order thinking skills, consistent with findings that student-centered interactive multimedia strengthens critical reasoning in science learning (Safira et al., 2024). The product is further intended to serve as a practical reference for teachers seeking to design more innovative, technology-based, twenty-first-century instruction. Accordingly, this study aims to develop the RAJA MAKAN digital interactive multimedia through the ADDIE model to improve elementary students' critical thinking skills on ecosystem material, with the resulting product's validity, practicality, and effectiveness examined as part of the Evaluation phase to support its overall feasibility.

2. LITERATURE REVIEW

2.1 Critical Thinking in Elementary Science Education

Critical thinking is widely regarded as a foundational competency that enables learners to analyze information, evaluate arguments, and construct reasoned conclusions rather than simply memorizing facts. Ennis (1996) defines critical thinking as reasonable and reflective thinking that is focused on deciding what to believe or do, a definition that has become a common reference point for measuring higher-order reasoning in classroom-based research. Within the Indonesian context, this competency has been positioned as a central pillar of the Merdeka Curriculum and the Pancasila Student Profile, both of which emphasize student-centered and project-based instruction as a pathway toward independent and reflective learners (Ariani et al., 2023).

Despite this curricular emphasis, empirical findings continue to show that elementary students in Indonesia generally perform at a low-to-moderate level of critical thinking. Classroom practice is still frequently dominated by rote memorization and factual recall rather than by activities that require students to question, argue, or connect concepts to real situations (Mahardika et al., 2025). This condition indicates a persistent gap between the aspiration stated in curriculum policy and the reality of everyday classroom instruction, particularly in subjects such as Natural and Social Sciences (IPAS) where abstract concepts are often delivered through textbook-centered lecturing.

2.2 Deep Learning Approach in Science Instruction

The deep learning approach offers one pedagogical response to the limitations of lecture-centered instruction. This approach directs students to move beyond surface-level memorization toward meaningful understanding, reflection, and the deliberate connection of concepts to authentic experience (Fitriani et al., 2026). Rather than positioning students as passive recipients of information, deep learning requires them to actively construct knowledge through exploration, collaboration, and reflective problem-solving.

Recent studies support the effectiveness of this orientation in basic education settings. Weng et al. (2023) found that instructional designs emphasizing active and reflective engagement produce more durable conceptual understanding compared to transmission-based teaching. Similar findings were reported by Ambarita et al. (2025) and Manik et al. (2025), who argued that the structured integration of deep learning principles into curriculum implementation is a decisive factor in translating pedagogical intent into measurable learning outcomes. These findings collectively suggest that combining a deep learning orientation with an appropriately designed instructional medium holds strong potential for improving elementary students' critical thinking performance.

2.3 Digital Interactive Multimedia as a Learning Medium

The rapid development of digital technology has expanded opportunities to design learning media that are more interactive, immersive, and contextually relevant to students' daily experience. Interactive multimedia that integrates animation, simulation, and reflective assessment has been shown to increase motivation, engagement, and critical thinking more effectively than lecture-dominated instruction (Andayani et al., 2025). This effect is theoretically supported by the cognitive theory of multimedia learning, which explains that the coordinated use of text, imagery, and audio can reduce cognitive load and strengthen comprehension when the elements are designed according to principles of coherence and consistency (Mayer, 2024; Mayer & Fiorella, 2021).

Evidence from recent development research reinforces this pattern. Alyusfitri et al. (2024) demonstrated that interactive e-modules delivered through familiar digital platforms produce measurable gains in student learning outcomes when properly aligned with curriculum objectives. A meta-analysis by Juwanda et al. (2025) further confirmed that the development of interactive multimedia consistently enhances students' critical thinking performance across multiple educational levels, including elementary school. However, prior studies also indicate that this benefit is not automatic. Several media development projects have concentrated primarily on improving material visualization and general motivation without deliberately embedding a strategy to cultivate critical thinking (Daniar & Sari, 2022; Sastradewi, 2022). This pattern identifies a research gap that the present study seeks to address, namely the development of interactive multimedia that is deliberately structured around a deep learning approach to sharpen elementary students' critical thinking on ecosystem material.

2.4 The ADDIE Model as a Development Framework

The ADDIE model, comprising the five phases of Analysis, Design, Development, Implementation, and Evaluation, is one of the most widely used frameworks for developing instructional products because of its systematic yet adaptive structure (Branch, 2010). Each phase produces a specific output that becomes the reference for the following phase, allowing continuous refinement through formative evaluation so that the resulting product remains responsive to the needs of both teachers and students (Sugiono, 2016). Theoretically, ADDIE is grounded in a systems-design perspective on instruction, in which each phase functions as an interdependent subsystem. The Analysis phase diagnoses the gap between current and desired learner performance and characterizes the target audience, providing the empirical foundation for the following phases. The Design phase translates these findings into measurable performance objectives, an assessment strategy, and a content blueprint, so that later design decisions remain traceable to an identified instructional need. The Development phase operationalizes the design into a tangible product through content creation, media production, and formative validation, while the Implementation phase prepares teachers and learners to use the product under classroom conditions. The Evaluation phase runs throughout the cycle as formative evaluation and concludes it with summative evaluation, determining whether the product meets the criteria of validity, practicality, and effectiveness. This formative and cyclical character makes ADDIE particularly suited to R&D studies, which need to demonstrate a traceable, evidence-based development process alongside a finished product.

Application of the ADDIE model in prior research has shown that a structured development sequence contributes directly to the quality of the resulting instructional product. Abas (2025), for example, found that curriculum-aligned design produced by a systematic ADDIE process resulted in strong practicality ratings from teacher users. This body of evidence provides the methodological foundation for adopting the ADDIE model in the present study to develop, validate, and test the RAJA MAKAN digital interactive multimedia on ecosystem material.

3. RESEARCH METHOD

3.1 Research Design

This study employed a Research and Development (R&D) approach directed at producing a digital interactive learning medium capable of improving elementary students' critical thinking skills. The R&D approach was selected because the study sought not only conceptual findings but also a tangible product that satisfies the criteria of validity, practicality, and effectiveness for classroom use. The development procedure followed the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation), chosen for its formative and cyclical nature, which allows continuous refinement through expert review and field trial (Branch, 2010; Sugiono, 2016). Each phase is described below according to its purpose, main activities, participants, instruments, procedure, and resulting output.

1) Analysis phase

This phase aimed to identify the gap between current instructional practice and the desired critical-thinking competency, and to profile the characteristics of the target learners. Activities consisted of direct classroom observation, semi-structured interviews with the classroom teacher, and a review of the Grade V IPAS curriculum's learning outcomes. Participants were the classroom teacher and students of SD Zainuddin Waru Sidoarjo. The instrument used was an observation and interview guide. The procedure involved several rounds of classroom observation, an interview on recurring instructional obstacles, and a review of curriculum documents and available technological infrastructure. The output was a needs-analysis summary describing instructional conditions, learner characteristics, curriculum alignment, and available resources.

2) Design phase

This phase aimed to translate the needs-analysis findings into a concrete product blueprint. Activities included formulating performance objectives mapped to Ennis's (1996) critical-thinking indicators, structuring the multimedia narrative and content across two learning sessions, and drafting the assessment instruments used for validity, practicality, and effectiveness testing. The researcher worked from the Analysis-phase findings using a design blueprint template covering objectives, content outline, and assessment plan. The output was a design brief specifying the two-session content structure, the RIMA and RAMA detective narrative, and the draft instruments used in the following phases.

3) Development phase

This phase aimed to produce a functioning multimedia product and to secure its content and design quality through expert review before field use. Activities consisted of building the product on the Canva Website platform, integrating narrative-based problem scenarios, animated video, an Educaplay interactive quiz, and digital worksheets, followed by expert validation and a small-group trial. Participants were one material expert, one media expert, and six fifth-grade students in the small-group trial. Instruments used were the material and media expert validation sheets (Section 3.3). The procedure involved distributing the validation sheets to both experts, revising the product based on their scores and written suggestions (Table 3), and piloting the revised product with the small group to check usability before large-scale use. The output was a validated instructional product ready for classroom implementation.

4) Implementation phase

This phase aimed to prepare teachers and students to use the multimedia under classroom conditions and to deliver the intervention. Activities consisted of a brief orientation for the teacher and students, followed by classroom delivery of the two learning sessions to the small group and then to the large group. Participants were the classroom teacher and 21 fifth-grade students (6 in the small-group trial and 15 in the large-group trial). Delivery followed the lesson design produced in the Design phase. The output was a fully delivered instructional sequence across four sessions in total, forming the basis for the Evaluation phase.

5) Evaluation phase

This phase aimed to determine whether the developed multimedia met the criteria of validity, practicality, and effectiveness. Activities consisted of administering teacher and student practicality questionnaires immediately after implementation, and administering the critical thinking test as a pretest before the intervention and a posttest afterward. Participants were the classroom teacher and the 21 students above, with the 15 large-group students serving as primary respondents for the pretest-posttest effectiveness measurement. Instruments used were the practicality questionnaires and the ten-item critical thinking test (Section 3.3). The output was the evaluation report presented in Section 4.

Table 1 below summarizes the five ADDIE phases together with their corresponding procedures and expected outputs, providing an overview of how each stage of development connected to the next.

Table 1. Summary of the ADDIE Development Procedure Applied in This Study

Phase	Main Procedures	Expected Output
Analyze	Validating performance gaps, formulating instructional objectives, profiling learner characteristics, identifying resources	Needs analysis summary
Design	Task inventory, performance objective formulation, assessment strategy, cost-benefit consideration	Design brief
Develop	Content development, supporting media selection, learner and teacher guides, formative revision, pilot testing	Instructional product (learning resource)
Implement	Teacher and student preparation for classroom use	Implementation strategy
Evaluate	Determining evaluation criteria, selecting evaluation tools, conducting evaluation	Evaluation report (validity, practicality, effectiveness)

Source: Adapted from Branch (2010) and the study's development procedure, 2026

Table 1 shows that each phase generated a specific document or output that became the reference for the subsequent phase, ensuring that the development process proceeded systematically. This structured flow forms the basis of the sampling, instrumentation, data collection, and data analysis procedures described in the following sub-sections.

3.2 Research Respondents and Sample

Try-out subjects in this study consisted of two categories, namely expert validators and target users. The expert validators comprised a material expert and a media expert, each holding a minimum of a master's degree and at least two years of relevant teaching or design experience in their respective fields. These two validators were purposively selected because of their competence in assessing the accuracy of ecosystem content and the quality of multimedia interface design.

The target users were fifth-grade students of SD Zainuddin Waru Sidoarjo, selected through a purposive sampling technique in two successive trial groups. The small-group trial involved six students and served solely to gather formative feedback for product revision before full implementation; students in this group did not participate in the pretest-posttest effectiveness measurement. The large-group trial involved fifteen students who completed both the pretest and posttest of the critical thinking instrument, making them the primary respondents for the effectiveness analysis. In total, twenty-one students participated across both trial groups, together with one classroom teacher who provided the teacher practicality response.

3.3 Research Instruments

Data in this study were collected through three main instruments. The first instrument was an expert validation sheet, used to measure the validity of the multimedia content and design. The material expert evaluated thirteen statement items covering objective alignment, content accuracy, and learning-aid adequacy, while the media expert evaluated twenty-seven items covering interface design, content design, and connectivity. Both instruments used a five-point rating scale.

The second instrument was a user response questionnaire, administered separately to the teacher and to the students to measure the practicality of the multimedia after classroom implementation. The teacher questionnaire consisted of ten items addressing accessibility, sequencing, and instructional impact, while the student questionnaire addressed attractiveness, navigational ease, and perceived contribution to conceptual understanding. The third instrument was a ten-item multiple-choice critical thinking test, developed based on Ennis's (1996) critical thinking indicators and administered as a pretest and posttest to measure the effectiveness of the multimedia in improving students' critical thinking on ecosystem material.

3.4 Data Collection Technique

Data collection followed the sequence of the ADDIE phases described in the research design. During the Analysis phase, data were collected through direct classroom observation and semi-structured interviews with the classroom teacher to identify instructional gaps and profile students' characteristics. During the Development phase, the expert validation sheets were distributed to the material expert and the media expert, who reviewed the product independently and provided a numerical score for each item together with written suggestions for revision. During the Implementation phase, the multimedia was delivered directly in the classroom across four instructional sessions in total, consisting of two learning sessions administered to the small-group trial and the same two learning sessions subsequently administered to the large-group trial. Practicality questionnaires were distributed to the teacher and to all twenty-one students immediately after this classroom implementation. The critical thinking test was administered to the fifteen large-group students twice, once before the intervention as a pretest and once after the intervention as a posttest, following the same test items and testing conditions on both occasions to ensure comparability of the resulting scores.

3.5 Data Analysis Technique

Data obtained from the expert validation sheets and the user response questionnaires were analyzed descriptively using a percentage formula, in which the score achieved by each validator or respondent was compared against the maximum expected score. The resulting percentage was then interpreted using an established category table ranging from invalid to very valid for the validity criterion, and from impractical to very practical for the practicality criterion.

Data from the pretest and posttest critical thinking test were analyzed through three complementary procedures. First, classical mastery was calculated by determining the percentage of students who reached the minimum mastery criterion (KKM $\geq$ 75) before and after the intervention. Second, an individual N-Gain score was calculated for each student by comparing the actual score gain against the maximum possible gain, and the resulting scores were categorized into high, moderate, and low gain categories. Third, because the posttest data did not satisfy the normality assumption required for a parametric paired t-test, as confirmed by the Shapiro-Wilk test, a one-tailed Wilcoxon Signed-Rank Test was applied to determine the statistical significance of the pretest-posttest difference (Istyasiwi et al., 2021). The developed multimedia was considered effective when the N-Gain fell in the moderate-to-high category, the Wilcoxon test showed a significant pretest-posttest difference, and at least 75 percent of students classically achieved the minimum mastery criterion.

4. RESULT

The results of this study are presented according to the five phases of the ADDIE model, namely Analysis, Design, Development, Implementation, and Evaluation. Presenting the findings in this sequence allows readers to trace how each phase produced specific outputs, what revisions were made, and what challenges emerged during the development process.

4.1 Analysis Phase Result

The Analysis phase identified that classroom instruction at the research site remained lecture-dominated with minimal use of interactive media, that fifth-grade students (10–11 years old) were at Piaget's concrete-operational stage and therefore required concrete visual representation of abstract ecosystem concepts, and that the school possessed adequate device and internet infrastructure to support a web-based multimedia format. These findings were synthesized into a needs-analysis summary, presented in Table 2, which subsequently guided the design of the multimedia narrative built around two junior-detective characters, RIMA and RAMA, investigating a case of ecosystem damage in a Sumatran forest.

Table 2. Summary of Needs Analysis for RAJA MAKAN Multimedia Development

Analysis Aspect	Condition Found	Identified Need
Instructional condition	Lecture-based, minimal interactive media	Interactive and engaging digital media
Student characteristics	Age 10–11, concrete-operational stage	Concrete and contextual visualization
Curriculum alignment	Grade V IPAS, Ecosystem Harmony topic	Media aligned with learning outcomes
Critical thinking level	Low, unfamiliar with HOTS items	Analytical tasks and activities
Technological resources	Adequate computer/device access	Web-based accessible media

Source: Primary research data, 2026

These findings were obtained through three complementary activities, namely direct classroom observation conducted across several sessions, semi-structured interviews with the classroom teacher regarding recurring instructional obstacles, and a document review of the Grade V IPAS curriculum learning outcomes together with the school's available technological infrastructure. No revision was required at this stage, as the Analysis phase produced the initial reference used to formulate the Design phase. No significant obstacles were encountered at this stage due to full cooperation from the school and the classroom teacher.

4.2 Design Phase Result

The Design phase produced a two-session multimedia structure comprising 65 slides in total, with the first session (35 slides) covering problem orientation, biotic-abiotic exploration, an Educaplay quiz, and a digital worksheet on food-web construction, and the second session (30 slides) covering ecosystem-damage data analysis, group discussion, reflection, and a final critical thinking assessment. Each slide was designed in accordance with the principle of multimedia unity between text, imagery, and animation to minimize students' cognitive load.

This design blueprint was formulated by mapping performance objectives to Ennis's (1996) critical-thinking indicators, structuring the detective-themed narrative, and drafting the validation and testing instruments used in the subsequent phases.

4.3 Development Phase Result

At this stage, all components designed during the Design phase, including the interface display, instructional content, interactive activities, video, assessment, and the supporting features of the deep learning approach, were integrated into a single digital learning medium built on the Canva Website platform. Each page was developed with attention to the principles of user-friendliness, readability, design consistency, and the developmental characteristics of elementary learners so that the resulting experience would be engaging, meaningful, and interactive. The outcome of the RAJA MAKAN digital interactive multimedia development is presented below.

Figure 1. Landing Page of the RAJA MAKAN Digital Interactive Multimedia

The landing page was developed as the initial display that introduces the identity of the RAJA MAKAN digital interactive multimedia to learners. This page presents the media title, an illustration of the detective characters, an animal mascot, a start button, and an environmental illustration relevant to the ecosystem topic, all intended to capture students' attention from the very beginning of the lesson. The visual design combines a green color palette, forest imagery, and cartoon-style characters to create a pleasant learning atmosphere suited to the characteristics of elementary school students. Beyond serving as the media's visual identity, this page also functions as the entry point through which learners begin the entire structured learning sequence.

Figure 2. Learning Selection Page of the RAJA MAKAN Digital Interactive Multimedia

The learning selection page was developed to give learners flexibility in choosing which session to study in accordance with the pre-designed learning flow. This page provides navigation buttons leading to Learning Session 1 and Learning Session 2, allowing students to move easily between the two instructional sequences. The button layout was kept simple and proportionally sized so that it could be easily recognized and operated by young learners. The provision of this selection menu supports the principle of usability, enabling students to access the intended material independently.

Figure 3. Learning Menu of the RAJA MAKAN Digital Interactive Multimedia

The learning menu functions as the central navigation hub connecting all instructional components within the digital interactive multimedia. This page provides access to the learning objectives, material and worksheets, assessment, and reflection sections, all arranged in accordance with the stages of the deep learning approach. The recurring presence of the characters Rima and Rama on this page reinforces narrative continuity while simultaneously increasing learner engagement throughout the lesson. The systematic arrangement of this menu allows students to follow each stage of learning sequentially without becoming confused about where to navigate next.

Figure 4. Learning Objectives Page of the RAJA MAKAN Digital Interactive Multimedia

The learning objectives page was developed to provide learners with a clear picture of the competencies they are expected to achieve upon completing the lesson. The objectives were formulated based on the Grade V IPAS learning outcomes and expressed through operational verbs directed at critical thinking ability. In addition to stating the competencies, this page also delivers initial motivation through a narrative that invites students to take on the role of a detective in resolving an ecosystem-related problem. Presenting the learning objectives at this early stage helps students understand the direction and target of their learning before proceeding to the core material.

Figure 5. Islamic Paradigm Page of the RAJA MAKAN Digital Interactive Multimedia

The Islamic Paradigm page was developed as an implementation of value integration within IPAS instruction, connecting scientific content with religious reflection. This page presents Surah Al-Furqan verse 2 of the Qur'an together with an explanation that links the concept of ecosystem balance to the greatness of God. Placing this religious reflection toward the end of the page encourages students to relate scientific concepts to spiritual values, thereby making the learning experience more meaningful. This integration simultaneously supports the cultivation of religious character without reducing the depth of the scientific content being taught.

Figure 6. Problem-Orientation Video of the RAJA MAKAN Digital Interactive Multimedia

The orientation video was developed as an initial stimulus to build learners' curiosity about the problem they are about to investigate. The video depicts a condition of forest damage that marks the beginning of Rima and Rama's investigative journey to uncover the causes of ecosystem imbalance. This presentation is intended to capture attention, provoke cognitive conflict, and encourage students to engage in the process of problem identification. Through this approach, the lesson begins with a contextual experience that closely resembles a real-world situation rather than an abstract textbook scenario.

Figure 7. Detective Case Scenario Page of the RAJA MAKAN Digital Interactive Multimedia

The case scenario page presents a contextual problem in the form of an interactive story involving Rima and Rama as junior detectives. Through the dialogue displayed on this page, students are invited to identify the problem, gather relevant information, and formulate an initial hypothesis regarding the cause of the ecosystem damage. The storyline was deliberately designed to train students in questioning, analyzing information, and constructing evidence-based arguments. This narrative approach is expected to strengthen both the emotional and cognitive engagement of learners throughout the instructional process.

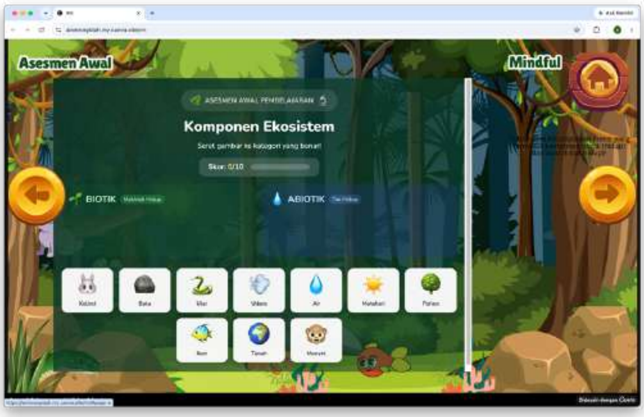

Figure 8. Assessment Page of the RAJA MAKAN Digital Interactive Multimedia

The assessment page was developed to identify students' prior knowledge of biotic and abiotic components before the core lesson begins. The activity is presented as a drag-and-drop game in which students interactively sort objects into their appropriate categories. A real-time scoring feature provides immediate feedback on students' initial level of understanding as they complete the task. This form of assessment supports active learning while simultaneously boosting motivation through an enjoyable, game-based activity.

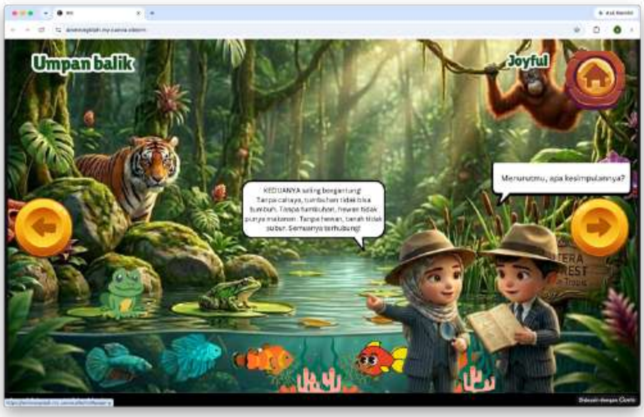

Figure 9. Feedback and Reflection Page of the RAJA MAKAN Digital Interactive Multimedia

The feedback page was developed as a means for students to conclude the learning they have completed. Through character dialogue and ecosystem illustrations, students are guided to understand the interdependent relationship between biotic and abiotic components in maintaining ecosystem balance. Reflective questions presented at the end of this page prompt students to express their views based on the analysis they conducted throughout the lesson. Through this activity, students not only acquire conceptual knowledge but also engage in reflection on the meaning of what they have learned.

During the Development phase, the prototype underwent formative revision by two validators; eight aspects were revised, including the completeness of the ABCD-format learning objectives, the clarity of the food-chain concept to avoid misconceptions, the addition of scaffolded reflective questions, and the incorporation of sound effects into moving animations, as summarized in Table 3.

Table 3. Comparison of the Product Before and After Formative Revision

No.	Revised Aspect	Condition Before Revision	Condition After Revision
1.	Learning objectives	Lacked measurable condition and degree components	Complete ABCD-format objectives
2.	Food-chain concept	Potential for misconception	Clarified with accurate visualization
3.	Reflective questions	Presented without guidance	Equipped with scaffolded prompts
4.	Image-text composition	Not adjusted to students' cognitive level	Adjusted to Grade V cognitive development
5.	Evaluation item wording	Some items implied the answer	Revised to remove implicit cues
6.	Multiple-choice option length	Disproportionate option length	Proportional and balanced options
7.	Button navigation	Inconsistent slide direction	Corrected sequential navigation
8.	Animation sound effect	No dialogue audio	Added synchronized dialogue audio

Source: Primary research data, 2026

Material and media validity were assessed by two expert validators using a five-point scale. The material expert evaluated 13 statement items covering objective alignment, content accuracy, and learning-aid adequacy, while the media expert evaluated 27 items covering interface design, content design, and connectivity, as summarized in Table 4.

Table 4. Recapitulation of Expert Validation Results

Validator	Number of Items	Score Achieved	Maximum Score	Percentage	Category
Material expert	13	57	65	87.7%	Very valid
Media expert	27	117	135	86.7%	Very valid
			Average	**87.2%**	**Very valid**

Source: Primary research data, 2026

The highest material-expert scores were recorded for content completeness and comprehensibility, while the lowest media-expert score (3 out of 5) was assigned to the moving-animation item, which lacked accompanying audio before the revision described in Table 3. Both validators nonetheless classified the product as very valid and suitable for classroom implementation without substantial further revision.

This lowest score functioned as the main challenge identified during the Development phase. The solution applied was to add synchronized dialogue audio to the moving animation, as summarized in the eighth revised aspect in Table 3, so that the product's design quality met the very valid criterion before proceeding to the Implementation phase.

4.4 Implementation Phase Result

Following the completion of the validated product, the Implementation phase was carried out through a brief orientation for the teacher and students, followed by classroom delivery of the two learning sessions to the small group and subsequently to the large group, resulting in four instructional sessions in total. The teacher and 21 fifth-grade students (6 in the small-group trial and 15 in the large-group trial) directly operated the RAJA MAKAN multimedia during this stage, covering problem orientation, biotic-abiotic exploration, ecosystem-damage data analysis, and the reflective assessment sequence designed in the Design phase. The teacher respondent assigned the maximum score to nine of ten items, with the only reduced score (4 out of 5) attributed to the technical performance of supplementary features such as video and audio on certain devices.

This finding indicates that the main challenge encountered during the Implementation phase was a technical constraint related to device compatibility rather than the instructional design itself. The solution applied was to ensure a stable internet connection was available before each session and to pre-load the multimedia content on the classroom devices, minimizing disruption caused by the technical constraint during implementation.

4.5 Evaluation Phase Result

The Evaluation phase was carried out to determine whether the developed multimedia met the criteria of practicality and effectiveness, through administration of the teacher and student practicality questionnaires and the pretest-posttest critical thinking test. Practicality was measured through teacher and student response questionnaires administered after direct classroom implementation, which took place across four instructional sessions in total, consisting of two learning sessions delivered to the small-group trial and the same two learning sessions subsequently delivered to the large-group trial, involving a total of 21 students (6 in the small-group trial and 15 in the large-group trial). Table 5 presents the recapitulation of both practicality results.

Table 5. Recapitulation of Teacher and Student Practicality Response

Respondent	Percentage	Category
Teacher (n = 1)	98%	Very practical
Student (n = 21)	93%	Very practical
Average	**95.5%**	**Very practical**

Source: Primary research data, 2026

Students similarly reported high satisfaction with the media's attractiveness, navigation clarity, and its contribution to their conceptual understanding of ecosystem material. Effectiveness was determined from the pretest-posttest critical thinking scores of 15 students who completed the full trial sequence. Table 6 presents the classical mastery comparison, and Table 7 presents the individual N-Gain results.

Table 6. Classical Mastery Comparison Between Pretest and Posttest

Indicator	Pretest	Posttest
Class mean score	73.33	90.67
Number of students reaching KKM (≥75)	8 of 15	14 of 15
Classical mastery percentage	53.3%	93.3%

Source: Primary research data, 2026

Table 7. Distribution of Student N-Gain Categories

N-Gain Category	Criterion	Number of Students
High	$g \geq 0.70$	8
Moderate	$0.30 \leq g < 0.70$	6
Low	$g < 0.30$	1
Average N-Gain		**0.72 (High)**

Source: Primary research data, 2026

Since the posttest distribution did not satisfy the normality assumption (Shapiro-Wilk sig. = 0.014), a one-tailed Wilcoxon Signed-Rank Test was applied. The result yielded Z = -3.482 with an Asymp. Sig. (2-tailed) of 0.000, corresponding to a one-tailed significance of 0.000, well below the 0.05 threshold. All 15 students showed positive ranks with zero negative ranks and zero ties, indicating a consistent improvement in critical thinking scores from pretest to posttest across the entire sample. Because the posttest distribution did not satisfy the normality assumption, the analytical challenge at this stage was determining an appropriate significance test. The solution applied was to switch from a parametric paired t-test to a one-tailed Wilcoxon Signed-Rank Test, which remained suitable for the paired pretest-posttest data despite the non-normal distribution.

5. DISCUSSION

The RAJA MAKAN multimedia developed in this study satisfied all three quality criteria of an instructional product, namely validity, practicality, and effectiveness, as evidenced through expert validation, user response data, and the critical thinking test. This overall pattern is consistent with the established principle that a well-designed instructional medium must simultaneously demonstrate validity, practicality, and effectiveness to be considered feasible for classroom use (Kristanto, 2016). The average validity score of 87.2 percent, the average practicality score of 95.5 percent, and the significant Wilcoxon test result together form a coherent body of evidence supporting the product's feasibility. Each criterion was obtained through a distinct measurement procedure yet converged toward the same conclusion regarding the product's quality. The convergence of three independent lines of evidence strengthens the credibility of the overall claim rather than relying on a single indicator. This alignment across criteria, discussed in the following subsections, is examined against the study's original objectives and situated within the broader body of prior research (Istyasiwi et al., 2021).

The material validity result of 87.7 percent was obtained from a validator's structured assessment of thirteen statement items covering content accuracy, curriculum alignment, and learner comprehensibility. This score was reached through a sequential process in which the validator scored each item, the scores were summed against the maximum expected total, and the resulting percentage was categorized according to an established validity criterion table. The finding aligns with recent evidence that interactive multimedia validated through a structured expert-review process tends to achieve a very valid classification when content development explicitly references curriculum learning outcomes (Susanto & Hapudin, 2024). At the same time, other augmented-reality-based interactive media studies have reported comparatively lower initial validity scores before revision, reflecting that content accuracy in interactive science media is highly sensitive to the thoroughness of the formative review cycle (Syawaludin et al., 2019). The gap between these two outcomes suggests that validity is not an automatic property of interactivity itself but a product of deliberate expert-guided refinement. Taken together, this comparison indicates that the high material validity obtained in the present study reflects the rigor of its formative revision process rather than the multimedia format alone.

From the media design perspective, the validator awarded particularly high scores to the clarity of learning-objective presentation, the logical sequencing of content, and the availability of specific feedback for each student response. This pattern indicates that RAJA MAKAN successfully implemented effective multimedia design principles, integrating text, imagery, animation, and audio to reduce cognitive load and strengthen comprehension, consistent with the cognitive theory of multimedia learning (Mayer, 2024). The one area receiving a reduced score, namely animation without accompanying audio, was subsequently corrected based on validator feedback, illustrating how formative revision functions as a critical safeguard for technical and pedagogical quality before field implementation (Jannah, 2020). A comparable finding was reported in a physics-based interactive multimedia simulation, where content and design quality also improved substantially only after a formal expert validation cycle was completed (Putri & Sofyan, 2020). This recurring pattern across different subject areas suggests that expert-guided iteration, rather than the underlying software platform, is the primary driver of design validity. The consistency of this mechanism across studies strengthens confidence that the revision-based validation procedure applied in this study was methodologically sound.

Teacher practicality reached 98 percent, driven primarily by favorable perceptions of the medium's clarity of navigation, completeness of content, and ease of classroom deployment. This result was obtained after the teacher directly operated the multimedia across four instructional sessions and subsequently completed a ten-item response questionnaire reflecting on accessibility, sequencing, and instructional impact. The finding is consistent with prior research showing that interactive multimedia grounded in a well-structured scientific approach and an intuitive interface tends to receive very high practicality ratings from educator users (Fitriyana et al., 2024). A comparable pattern was found in a study on Merdeka Curriculum-aligned instructional design, where teachers similarly reported strong practicality when the instructional design process explicitly incorporated curriculum objectives into its structure (Abas, 2025). Both findings point toward curriculum alignment, rather than technological sophistication alone, as the primary determinant of teacher acceptance. The consistency between the present result and these prior studies therefore reinforces the conclusion that a media's practicality for teachers is closely tied to how well it is integrated with established instructional planning processes.

Student practicality reached 93 percent, reflecting fifth-grade learners' generally favorable perception of the medium's attractiveness, navigational ease, and support for conceptual understanding. This outcome emerged after students completed the same lesson sequence as the teacher and responded to items addressing accessibility, feature functionality, and perceived learning impact. The result is consistent with the principle that instructional media combining verbal and visual elements in a balanced manner tend to increase motivation and active engagement among young learners (Mayer & Fiorella, 2021). Complementary evidence from a video-animation-based science medium likewise found that elementary students respond positively to media specifically designed around their developmental characteristics and interests (Sae & Radia, 2023). Not all studies report uniformly high student practicality, however, as some interactive e-module trials have documented more moderate satisfaction levels when navigational complexity was not sufficiently simplified for younger users (Alyusfitri et al., 2024). This divergence highlights those design decisions regarding interface simplicity, rather than the mere presence of interactive features, substantially shape how practical young learners perceive a digital medium to be. The consistently high student practicality obtained in this study therefore reflects the deliberate simplification embedded in the RAJA MAKAN interface design.

Classical mastery increased markedly from 53.3 percent at pretest to 93.3 percent at posttest, exceeding the 75 percent threshold required to classify the medium as effective. This increase was obtained through a structured two-session implementation in which students progressed from problem orientation and biotic-abiotic exploration in the first session to ecosystem-damage analysis and reflective evaluation in the second session, culminating in the posttest measurement. The magnitude of this improvement is consistent with meta-analytic evidence indicating that interactive multimedia development consistently enhances students' critical thinking performance across multiple educational levels, including elementary school (Juwanda et al., 2025). A parallel finding was reported in a food-chain-specific interactive media study, which similarly demonstrated substantial gains in students' conceptual mastery of ecosystem-related content following structured multimedia intervention (Mulyono et al., 2025). Both studies, conducted on comparable ecosystem or biology-related topics, converge in showing that carefully sequenced interactive instruction can substantially narrow the gap between initial and post-intervention mastery. This convergence supports the conclusion that the classical mastery gain observed here is attributable to the structured pedagogical sequencing embedded in the RAJA MAKAN design rather than to incidental factors.

The average N-Gain of 0.72, classified as high, indicated that the multimedia produced a substantial normalized improvement in students' critical thinking scores, with eight of fifteen students reaching the high category and only one student remaining in the low category. This result was derived from a per-student calculation comparing the actual score gain against the maximum possible gain, thereby accounting for each student's initial ability level rather than relying solely on raw score differences. The finding is consistent with research demonstrating that combining a deep learning approach with interactive media, through processes of exploration, discussion, and reflection, reliably produces high-category N-Gain outcomes among elementary learners (Syawaluddin et al., 2024). Similarly, a study on problem-based interactive multimedia for science learning reported comparable high-category gains when the intervention emphasized active problem-solving rather than passive content delivery (Adhana & Andriani, 2024). Not every development study reaches this magnitude, however, since interventions with a narrower scaffolding structure or a shorter implementation period have sometimes produced only moderate normalized gains despite favorable validity and practicality scores (Panggabean et al., 2025; Weng et al., 2023). This variation suggests that the duration and depth of active engagement, rather than the technology itself, is a decisive factor separating high-category from moderate-category gains, a condition that the two-session, exploration-based structure of RAJA MAKAN appears to have satisfied.

The Wilcoxon Signed-Rank Test result, with Z = -3.482 and Asymp. Sig. (2-tailed) = 0.000, provided statistical confirmation that the improvement in critical thinking scores from pretest to posttest was significant rather than attributable to chance. This result was obtained by ranking the absolute differences between each student's paired scores and testing the direction and magnitude of those ranks against the null hypothesis, given that the posttest distribution failed the normality assumption required for a parametric test. All fifteen students exhibited positive ranks with no negative ranks and no ties, a pattern indicating that the direction of improvement was fully consistent across the sample. This finding aligns with research showing that a systematically structured deep learning approach supported by interactive media reliably produces statistically significant gains in critical thinking, because students are pushed to construct knowledge actively through analysis, evaluation, and synthesis rather than passive reception (Wulandari et al., 2023). The result is further reinforced by policy-oriented studies emphasizing that a structured integration of deep learning principles into curriculum implementation is a decisive factor in translating pedagogical intent into measurable learning outcomes (Ambarita et al., 2025; Manik et al., 2025).

Beyond its immediate pedagogical contribution, the development of RAJA MAKAN also carries implications relevant to the broader discourse on educational technology and development, particularly regarding equitable access to digital learning resources in under-resourced elementary schools. The reliance of the current prototype on a stable internet connection and the Canva Website platform reflects a common tension in technology-based educational development, namely the trade-off between rich interactivity and accessibility in schools with limited or inconsistent digital infrastructure, a concern central to the field of development studies and to the broader agenda of Sustainable Development Goal 4 on inclusive and equitable quality education. Situating this product within that wider development perspective suggests that future iterations should prioritize offline-capable deployment, not only as a technical refinement but as a deliberate equity measure to ensure that the demonstrated gains in critical thinking are attainable across schools with varying levels of digital access, rather than remaining confined to well-resourced settings. Taken together, these findings directly answer the study's objective: the RAJA MAKAN digital interactive multimedia was successfully developed through a systematic ADDIE process and is supported by convergent evidence of validity, practicality, and effectiveness. Beyond its immediate classroom benefit, this development process contributes a replicable model for building deep learning-structured, problem-oriented multimedia on other elementary science topics, extending the current body of R&D research that has largely focused on visualization or motivation alone.

6. CONCLUSION

This study successfully developed the RAJA MAKAN deep learning-based digital interactive multimedia through a systematic ADDIE procedure, beginning with the identification of instructional needs, followed by the formulation of a detective-themed, deep learning-structured design, expert-guided formative revision, and delivery and testing in an authentic classroom setting. The resulting product integrates narrative-based problem scenarios, video simulation, an interactive quiz, and reflective worksheets specifically structured to train elementary students' critical thinking on ecosystem material, distinguishing it from prior media that addressed visualization or motivation without a comparable pedagogical structure. This developmental achievement is supported by strong empirical evidence: material and media expert validation produced an average score of 87.2 percent, teacher and student practicality reached an average of 95.5 percent, and classical mastery increased from 53.3 percent to 93.3 percent with a high-category N-Gain of 0.72, further confirmed as statistically significant by the Wilcoxon Signed-Rank Test. These findings indicate that the objective of developing a practical and effective deep learning-based multimedia for elementary science instruction has been achieved, and that RAJA MAKAN is feasible for wider classroom implementation as an ecosystem learning resource.

The study nonetheless remains limited to a single elementary school and a relatively small trial sample, so the findings should be interpreted within this scope rather than generalized broadly. Future development is recommended to expand the subject pool across multiple schools and grade levels, examine additional twenty-first-century competencies such as creativity and collaboration, and explore an offline-capable version of the multimedia to reduce dependence on stable internet access. Teachers intending to adopt this medium are advised to conduct a brief orientation session beforehand to ensure optimal facilitation during classroom implementation.

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