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Development of RADEC-Based Deep Learning Lesson Planning to Enhance Fifth-Grade Students' Critical Thinking Skills in Integrated Science and Social Studies

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Abstract

Critical thinking is an essential 21st-century competency, yet its development in elementary education is often constrained by instructional planning that provides limited opportunities for higher-order thinking. This study developed and evaluated RADEC-based Deep Learning Lesson Planning integrating the *Read, Answer, Discuss, Explain,* and *Create* stages to support fifth-grade students' critical-thinking skills in Integrated Science and Social Studies (IPAS). Using a Research and Development approach with the ADDIE model, the study involved product development, expert validation, teacher evaluation, and limited implementation with 23 fifth-grade students in Bandung Regency during the 2025/2026 academic year. Data were collected through expert-validation instruments, a teacher-response questionnaire, and critical-thinking pretest and posttest assessments. Expert validation yielded scores of 90% for language and 95% for both subject matter and instructional design, while the teacher evaluation reached 92.85%, indicating high product feasibility and practicality. Students' mean critical-thinking score increased from 54.22 to 80.22, with a significant pretest–posttest difference, $t(22) = -10.552$, $p < .001$, and a mean N-Gain of 0.5605, representing moderate improvement. These findings provide preliminary evidence that the developed lesson planning is valid, practical, and associated with improved critical-thinking performance in IPAS. Further controlled studies with larger and more diverse samples are needed to establish its effectiveness and broader applicability.

Keywords: *Critical thinking, Deep Learning Lesson Planning, Elementary education, Integrated Science and Social Studies, RADEC.*

I. INTRODUCTION

Twenty-first-century education requires a shift from the mere acquisition of knowledge toward the development of competencies that enable learners to respond to increasingly complex social and global challenges. Critical thinking, creativity, collaboration, and communication (4C) have consequently become essential competencies that should be fostered from the elementary education level (Rahayu et al., 2022). Among these competencies, critical thinking is particularly important because it enables students to analyze information, evaluate arguments, connect evidence, and make rational and reflective decisions. In response to these demands, the Indonesian Ministry of Primary and Secondary Education has strengthened the implementation of the Kurikulum Merdeka through the Deep Learning approach, which emphasizes three core principles: mindful learning, meaningful learning, and joyful learning (Kemendikdasmen, 2025). Rather than replacing the existing curriculum, this approach is intended to strengthen learning processes by promoting more conscious, meaningful, and intellectually engaging learning experiences.

The Deep Learning approach positions students as active participants in exploring, interpreting, reflecting on, and applying knowledge. This orientation is consistent with the principles of the Kurikulum Merdeka, which emphasizes flexible, contextual, and learner-responsive instruction (Nabila et al., 2025). At the elementary school level, Deep Learning is particularly relevant because learning experiences should extend beyond information transmission and provide opportunities for students to construct understanding through experiences connected to their everyday contexts. These principles are applicable across subject areas, including Natural and Social Sciences (IPAS), where students are expected not only to acquire factual and conceptual knowledge but also to use reasoning to interpret natural and social phenomena.

In IPAS learning, critical thinking can be fostered through activities that require students to identify problems, explore information, discuss ideas, provide reasoned explanations, and generate solutions. Facilitating such processes requires instructional planning that translates the principles of

Deep Learning into systematic learning activities. Deep Learning Lesson Planning (Perencanaan Pembelajaran Mendalam [PPM]) should therefore provide opportunities for exploration, discussion, reflection, and creation, allowing students to participate actively in constructing knowledge. Systematically designed learning activities that facilitate higher-order thinking have been reported to contribute to the development of critical-thinking indicators among elementary school students (Erlinda et al., 2025). Similarly, active involvement in knowledge construction can strengthen students' conceptual understanding and critical-thinking skills (Nafi'ah & Faruq, 2025).

However, these expectations have not been fully reflected in students' competencies or current elementary classroom practices. The 2022 Programme for International Student Assessment (PISA) reported an Indonesian science score of 383, indicating persistent challenges in science competencies involving reasoning and the application of knowledge (OECD, 2023). At the elementary level, Jumanto et al. (2024) reported that 57% of the fourth-grade students examined were categorized as having low critical-thinking ability, particularly in decision evaluation. Similarly, Hayati and Setiawan (2022) found that more than two-thirds of fifth-grade students scored below 50% on a critical-thinking assessment in science learning. These findings indicate that developing critical thinking remains an important challenge that requires attention from the early stages of education.

This challenge is related not only to learner characteristics but also to how instruction is designed and implemented. Elementary classroom practices have been reported to remain oriented toward content delivery and learning exercises with relatively low cognitive demands, providing insufficient opportunities for students to engage consistently in analysis, argumentation, reflection, and problem solving (Anggrayni et al., 2025; Maylia et al., 2024). This situation reveals a gap between the orientation of Deep Learning, which emphasizes active cognitive engagement, and instructional practices that do not yet consistently facilitate higher-order thinking. Therefore, implementing PPM requires an instructional model with clear operational stages capable of translating Deep Learning principles into learning activities that explicitly stimulate critical thinking.

One model with potential to address this need is RADEC, which comprises five sequential stages: Read, Answer, Discuss, Explain, and Create. RADEC was developed by considering the characteristics and needs of the Indonesian educational context (Sopandi et al., 2023). Each stage provides a different opportunity for students to engage with knowledge. Read and Answer encourage students to independently acquire and process initial information; Discuss facilitates the exchange of ideas and evaluation of different perspectives; Explain enables students to construct and communicate their understanding; and Create encourages them to apply knowledge in generating ideas or solutions. This structure is particularly relevant to critical-thinking development because it incorporates processes of analysis, argumentation, evaluation, and knowledge construction.

Empirical studies have provided support for the implementation of RADEC in learning. RADEC has been reported to contribute to improvements in elementary students' critical-thinking skills and learning outcomes through activities involving analysis, argumentation, and reflection (Andriyani et al., 2024). The model also provides opportunities for higher-order thinking through structured discussions and creative problem-solving activities (Pahlevi, 2025). Furthermore, Rindiyani et al. (2026) reported greater improvement in critical thinking through RADEC than through conventional instruction. Collectively, these findings indicate that the instructional structure of RADEC has characteristics that are relevant to learning environments emphasizing deeper cognitive engagement.

Nevertheless, previous studies have predominantly examined RADEC as an instructional model directly implemented to improve learning outcomes or critical-thinking skills. Limited attention has been given to the systematic development of Deep Learning Lesson Planning (PPM) that explicitly integrates the RADEC syntax with the principles of mindful, meaningful, and joyful learning in elementary IPAS instruction. Moreover, empirical evidence regarding the quality of RADEC-based PPM as an instructional product—particularly in terms of its validity, practicality, and effectiveness in supporting students' critical-thinking skills—remains limited. Addressing this gap is important because successful instructional innovation depends not only on the selected learning model but also on the quality of the instructional planning through which its principles and procedures are translated into systematic learning experiences.

Accordingly, this study aimed to develop and evaluate RADEC-based Deep Learning Lesson Planning (PPM) for elementary IPAS instruction to support students' critical-thinking skills. The developed PPM systematically integrates the Read, Answer, Discuss, Explain, and Create stages with the principles of mindful, meaningful, and joyful learning. The quality of the developed product was evaluated in terms of its validity, practicality, and effectiveness, thereby providing both an integrated instructional planning product and empirical evidence regarding its feasibility and potential to support critical-thinking-oriented IPAS learning in elementary education.

II. METHOD

This study employed a Research and Development (R&D) approach to develop and evaluate an educational product through systematic processes of design, development, and validation (Gall et al., 2007). The product developed in this study was RADEC-based Deep Learning Lesson Planning (Perencanaan Pembelajaran Mendalam [PPM]) for elementary Natural and Social Sciences (IPAS), integrating the Read, Answer, Discuss, Explain, and Create stages. The development was directed toward supporting students' critical-thinking skills, particularly in alignment with critical reasoning as one of the competencies emphasized in the Kurikulum Merdeka.

The development process followed the ADDIE model, comprising Analyze, Design, Development, Implementation, and Evaluation. During the Analyze stage, observations and interviews were conducted to identify instructional needs, existing classroom problems, and requirements for product development. The Design stage involved constructing the instructional framework, organizing RADEC activities within the principles of Deep Learning, and developing the research instruments. During Development, the initial PPM was produced and subjected to expert judgment to determine its validity and provide recommendations for revision. The revised product was subsequently implemented in a limited field trial with fifth-grade students to obtain evidence regarding its practicality and preliminary effectiveness through user-response questionnaires and critical-thinking assessments. Evaluation was conducted formatively throughout the development process, with findings from expert review, user responses, and field implementation informing successive revisions and refinement of the final product. The ADDIE model was selected because its structured yet flexible and iterative characteristics enable continuous evaluation and improvement throughout educational product development (Hanila et al., 2025).

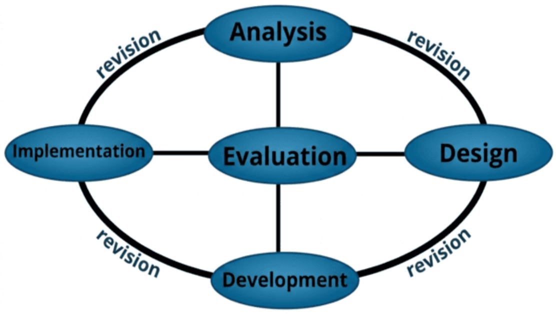

Figure 1. ADDIE Research and Development Stages

The study focused on RADEC-based PPM developed for fifth-grade IPAS instruction, specifically on the topics of ecosystems and food chains. The field trial was conducted during the second semester of the 2025/2026 academic year at an elementary school in Bandung Regency and involved 23 fifth-grade students. Fifth-grade students were selected because learners at this level are generally approaching the later phase of concrete operational development, in which logical reasoning and problem-solving abilities become increasingly developed (Piaget, 1972; Septiyanti et al., 2023). The characteristics of the selected IPAS content also provide opportunities for students to analyze relationships among ecosystem components and reason about problems involving food chains. In addition to the students, the study involved the classroom teacher as the user of the developed PPM and university lecturers with relevant expertise who participated in the expert-validation process.

Data were collected using both test and non-test techniques. Students' critical-thinking skills were assessed through pretest and posttest essay tests developed with reference to Ennis's (2011) critical-thinking framework. The instrument represented 12 sub-indicators: focusing questions, analyzing arguments, asking and answering clarification questions, judging source credibility, observing and evaluating observation reports, making deductions, making inductions, making value judgments, providing further clarification, identifying assumptions, deciding on actions, and interacting with others. Each sub-indicator was represented by one essay item, resulting in a total of 12 items. The instrument was subjected to expert judgment prior to implementation to examine the alignment between the items, indicators, content, and intended critical-thinking construct.

Non-test instruments consisted of interview protocols, expert-validation questionnaires, and a user-response questionnaire. Interviews were conducted during the analysis stage to identify existing instructional conditions and needs relevant to product development. Expert-validation questionnaires were administered to language, subject-matter, and instructional-design experts to evaluate the appropriateness of the developed PPM, whereas the user-response questionnaire was administered to the classroom teacher to assess product practicality. Expert comments and recommendations were also used as qualitative evidence for product revision. The practicality assessment was interpreted alongside expert-validation evidence and field-trial findings to provide a more comprehensive evaluation of the developed product.

Following validation and revision, the PPM was implemented with the participating students. Critical-thinking performance was measured before and after implementation using the pretest and posttest. The magnitude of improvement was additionally examined using the Normalized Gain (N-Gain), which expresses the observed improvement relative to the maximum possible improvement (Hake, 1999). N-Gain was used to provide standardized information regarding changes in students' critical-thinking performance following the intervention (Sundayana, 2020). The research instruments were evaluated for validity and reliability prior to their use to ensure that they were sufficiently appropriate for data collection.

Data were analyzed quantitatively and qualitatively according to their characteristics. Interview data and qualitative comments from validators were analyzed descriptively to identify instructional needs and recommendations for product refinement. Expert-validation and user-response questionnaire data were analyzed using descriptive statistics expressed as mean percentages and interpreted according to predetermined feasibility and practicality criteria. Students' critical-thinking scores were analyzed using both descriptive and inferential statistics. A normality test was first conducted on the pretest and posttest data to determine whether the assumptions for parametric analysis were satisfied. When the assumption of normality was met, a paired-samples t-test was used to examine whether students' critical-thinking scores differed significantly before and after the implementation of RADEC-based PPM. The magnitude of improvement was subsequently evaluated using N-Gain analysis. Together, these analyses were used to establish evidence regarding the validity, practicality, and preliminary effectiveness of the developed RADEC-based PPM.

III. RESULTS AND DISCUSSION

A. Results

The product developed in this study was RADEC-based Deep Learning Lesson Planning (Perencanaan Pembelajaran Mendalam [PPM]) for fifth-grade Natural and Social Sciences (IPAS), focusing on ecosystems and food chains. The developed PPM comprised several integrated instructional components, including lesson-planning information, learning materials, student worksheets (Lembar Kerja Peserta Didik [LKPD]), and assessment instruments and rubrics designed to evaluate students' critical-thinking skills. The product was systematically developed using the ADDIE model, consisting of five stages: Analyze, Design, Development, Implementation, and Evaluation, as described below.

1. Analysis Stage

The first stage of the development process was analysis, which served as a needs assessment to identify the instructional problems and requirements underlying product development. This stage is essential for systematically identifying the root causes of instructional problems and determining appropriate development priorities (Hidayat & Nizar, 2021). Accordingly, the analysis was not intended to generalize conditions beyond the research setting but to establish an empirical basis for developing the proposed product. Data were collected through classroom observation and an interview with a fifth-grade teacher at an elementary school in Ciparay District, Bandung Regency.

The initial analysis showed that the teacher had systematically prepared IPAS instruction through teaching modules and had attempted to incorporate contextual learning activities. The teacher was also familiar with the principles of the Deep Learning approach, including *mindful, meaningful,* and *joyful learning*, as well as several instructional models, including RADEC, which was considered relevant to supporting students' critical-thinking skills. However, translating these principles and models into consistent classroom practice remained challenging.

The observation and interview identified several constraints. Limited preparation time and substantial administrative responsibilities restricted the teacher's ability to design and implement instructional activities comprehensively, a challenge also reported in previous research on teachers' instructional responsibilities (Chaerany, 2024). Consequently, selected stages of instructional models were sometimes implemented separately rather than as a coherent sequence. The available learning materials also provided limited opportunities for higher-order thinking, while instructional media were insufficient to represent abstract IPAS concepts in more concrete and accessible forms. In addition, students demonstrated varying levels of critical-thinking performance and generally required visual stimuli, videos, or contextual cases to support the analysis of problems.

Based on these findings, three primary needs were identified: (1) a more systematic instructional plan that could assist teachers in implementing learning models within the available instructional time, (2) learning materials that more explicitly facilitate critical-thinking activities, and (3) instructional media that help represent abstract IPAS concepts through more concrete and contextual learning experiences. These needs provided the empirical basis for developing RADEC-based Deep Learning Lesson Planning (PPM). The PPM was therefore designed to integrate the *Read, Answer, Discuss, Explain,* and *Create* stages with the principles of *mindful, meaningful,* and *joyful learning*, while incorporating learning materials and instructional media intended to support students' critical-thinking development.

2. Design Stage

Following the identification of instructional needs, the next stage involved designing RADEC-based Deep Learning Lesson Planning (PPM) in accordance with the findings of the needs assessment. The developed PPM systematically integrated the RADEC stages—Read, Answer, Discuss, Explain, and Create—with the principles of the Deep Learning approach. To promote meaningful and contextual learning, the instructional activities connected IPAS concepts with students' everyday experiences. Accordingly, garden and marine ecosystems were selected as learning contexts because they provided relevant examples through which students could explore ecosystem relationships and food chains in situations closely related to their environment.

To address the limited classroom time identified during the analysis stage, the Read and Answer stages were designed as pre-class activities. One day before the face-to-face session, students were provided with reading materials and instructional videos to study independently at home as part of the Read stage. During the Answer stage, students completed a student worksheet (Lembar Kerja Peserta Didik [LKPD]) based on the assigned materials. In addition to activating students' prior understanding, the worksheet was used to encourage engagement with the pre-class materials and prepare students for subsequent classroom activities. Moving these two stages outside the face-to-face session allowed classroom time to be allocated more extensively to the cognitively demanding Discuss, Explain, and Create stages, in which students collaboratively examined ideas, articulated their understanding, and applied their knowledge through problem-solving and creative activities.

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Misteri Taman yang Sunyi

Di pinggir Desa Jatihurip, terdapat sebuah taman milik Pak Diki yang sangat terkenal. Dulu, taman ini adalah tempat paling indah; bunga-bunga bermekaran, buah mangganya manis dan banyak, serta banyak kupu-kupu warna-warni yang beterbangan. Namun, belakangan ini ada sesuatu yang aneh. Taman Pak Diki menjadi sunyi. Bunga-bunganya mulai layu sebelum sempat mekar, dan pohon mangganya tidak lagi menghasilkan buah.

Figure 2. Developed Learning Materials

The learning materials used during the Read stage of the Deep Learning Lesson Planning (PPM) were designed to provide contextual learning experiences by incorporating problems and phenomena from students' surrounding environment. This contextualization was intended to facilitate a deeper understanding of ecosystems and food chains by connecting scientific concepts with situations familiar to students. Contextual learning materials have been reported to contribute to the development of critical-thinking skills among elementary school students (Simanjuntak et al., 2023). In addition to written materials, instructional videos were provided and made accessible online through YouTube. The videos complemented the textual materials by offering audiovisual representations that could help students visualize IPAS concepts that may be difficult to understand through text alone. The use of instructional media that accommodates different modes of learning has also been associated with improved student learning outcomes (Rafli et al., 2024). Thus, the combination of contextual learning materials and audiovisual representations was incorporated into the PPM to support students' conceptual understanding and engagement in critical-thinking activities.

A student worksheet (Lembar Kerja Peserta Didik [LKPD]) was developed as a supporting component to facilitate students' engagement with the pre-class materials and document the development of their responses across the RADEC learning stages. The LKPD contained 10 essay questions that were used continuously across the Answer, Discuss, and Explain stages. During the Answer stage, students independently completed the questions at home after studying the assigned reading materials and videos, thereby generating their initial responses to the learning content. During the Discuss stage, the same questions were revisited collaboratively, and students recorded the results of their group discussions. Subsequently, during the Explain stage, students refined their responses based on whole-class discussion and teacher clarification. Using the same questions across these three stages enabled students to progressively examine, compare, and refine their initial ideas rather than responding to disconnected tasks at each stage.

The final component developed within the PPM was an assessment instrument designed to measure students' critical-thinking skills in the context of ecosystems and food chains. The assessment presented a problem-based narrative situated within a marine ecosystem as a common stimulus, followed by 12 essay questions developed with reference to the critical-thinking indicators proposed by Ennis (2011). Each item was designed to represent a specified aspect of critical thinking within the targeted IPAS content. The instrument was subsequently used in the pretest and posttest to generate empirical evidence regarding changes in students' critical-thinking performance following the implementation of the developed RADEC-based PPM.

3. Development Stage

All components systematically prepared during the design stage were transformed into concrete instructional materials during the Development stage. This stage operationalized the conceptual framework into a complete RADEC-based Deep Learning Lesson Planning (PPM) package that could be implemented by teachers in elementary IPAS instruction. Consistent with Branch (2009), the development stage of the ADDIE model focuses on producing and validating the instructional resources specified during the preceding design process.

Once the initial PPM was developed, it underwent expert validation to determine its appropriateness prior to field implementation. Expert validation served as an essential quality-assurance process for examining whether the developed product adequately met relevant content, linguistic, and instructional-design criteria. The validation involved experts in language, subject matter, and instructional design, each evaluating the product according to their respective areas of expertise. The language expert assessed the clarity, accuracy, readability, and appropriateness of the language used throughout the PPM components. The subject-matter expert evaluated the accuracy and relevance of the IPAS content and its alignment with the intended learning competencies, while the instructional-design expert examined the organization, systematic structure, learning activities, and alignment of the PPM with appropriate instructional-design principles.

The expert assessments and qualitative recommendations were subsequently analyzed and used as the basis for revising and refining the product before field implementation. The validation results indicated that the developed PPM achieved the "very valid" category across all three areas of expert evaluation, providing evidence of its appropriateness for proceeding to the implementation stage.

4. Implementation Stage

During the Implementation stage, the validated and revised RADEC-based Deep Learning Lesson Planning (PPM) was implemented to evaluate its practicality in elementary IPAS instruction. The classroom teacher, as the primary user of the product, evaluated the PPM using a user-response questionnaire covering its overall feasibility, alignment with the RADEC model, support for critical-thinking-oriented activities, and applicability to IPAS instruction. The questionnaire also provided space for comments and recommendations that were subsequently used as additional evidence for product refinement. The results of the user evaluation are presented in Table 1.

Table 1. User-Response Questionnaire Results

No.	Evaluation Aspect	Score
1	PPM Feasibility	15
2	Alignment with the RADEC Model	19
3	Support for Critical-Thinking Skills	7
4	Implementability in IPAS Learning	11
	Total Score	52
	Maximum Score	56
	Percentage	92.85%
	Category	Very Feasible

As shown in Table 1, the developed PPM obtained a total score of 52 out of a maximum of 56, corresponding to 92.85% and classified as very feasible. The teacher's evaluation indicated that the PPM was well structured and generally applicable to IPAS instruction on ecosystems and food chains. The assessment also showed favorable responses regarding the alignment of the learning activities with the RADEC stages and their potential to facilitate critical-thinking-oriented activities. These results provide evidence of the practicality and usability of the developed PPM from the teacher's perspective. However, the user-response questionnaire alone should not be interpreted as evidence of instructional effectiveness, as effectiveness was evaluated separately using students' pretest and posttest performance.

The teacher's qualitative feedback further indicated that the instructional plan was systematically organized and that the RADEC-based activities were perceived as supporting students' active participation, critical thinking, and learning motivation. Nevertheless, a practical constraint emerged during classroom implementation: several learning activities required more time than initially allocated. This discrepancy between the planned and actual instructional duration indicated the need to revise the time allocation, particularly for activities requiring discussion, explanation, and knowledge creation. The feedback was therefore incorporated into the subsequent evaluation and refinement of the PPM.

In addition to evaluating product practicality, the implementation stage examined the preliminary effectiveness of the RADEC-based PPM in supporting students' critical-thinking skills. A one-group pretest–posttest design was employed with 23 fifth-grade students. Students completed the critical-thinking assessment before and after the implementation of the PPM. The resulting pretest and posttest scores were subsequently analyzed using an inferential hypothesis test to determine whether a statistically significant difference occurred between the two measurements, while N-Gain analysis was used to quantify the magnitude of students' improvement relative to the maximum possible gain. These analyses provided empirical evidence regarding changes in critical-thinking performance following the implementation of the developed PPM.

Before hypothesis testing, the distribution of the pretest and posttest scores was examined using a normality test. The results are presented in Table 2.

Table 2. Normality Test Results

Test	Statistic	df	*p*	Interpretation
Pretest	.943	22	.208	Normally distributed
Posttest	.957	22	.401	Normally distributed

As shown in Table 2, the significance values for both the pretest ($p = .208$) and posttest ($p = .401$) were greater than .05, indicating no statistically significant departure from normality. Therefore, the data were considered appropriate for parametric analysis using a paired-samples t-test.

Table 3. Paired-Samples t-Test Results

Mean Difference	SD	SE	*t*	df	One-Sided *p*	Two-Sided *p*
-26.000	11.817	2.464	-10.552	22	< .001	< .001

The paired-samples t-test revealed a statistically significant difference between students' pretest and posttest critical-thinking scores, $t(22) = -10.552$, $p < .001$. The mean difference of -26.00 reflects the direction of the pretest-minus-posttest calculation, indicating that posttest scores were, on average, 26 points higher than pretest scores. Thus, students demonstrated significantly higher critical-thinking performance following the implementation of the RADEC-based PPM. Given the one-group pretest–posttest design, however, this finding should be interpreted as evidence of significant improvement following the intervention rather than definitive evidence that the improvement was caused exclusively by the developed PPM.

To complement the significance test and examine the magnitude of improvement relative to the maximum possible gain, students' scores were subsequently analyzed using N-Gain. The results are presented in Table 4.

Table 4. Descriptive Statistics of N-Gain Scores

Variable	N	Minimum	Maximum	Mean	SD
N-Gain	23	.23	.79	.5605	.14978

The mean N-Gain score was 0.5605, which falls within the moderate improvement category. This result provides complementary evidence that students' critical-thinking performance improved following the implementation of the developed PPM. Analysis across the critical-thinking sub-indicators further showed improvement across all assessed dimensions. The greatest improvement was observed in interacting with others, followed by observing and evaluating reports, while substantial improvement was also evident in analyzing arguments and deciding on actions. In contrast, making value judgments showed the smallest improvement among the assessed sub-indicators. These variations suggest that the learning activities may have supported different dimensions of critical thinking to different degrees.

5. Evaluation Stage

The Evaluation stage was conducted to synthesize evidence obtained throughout the development process and identify revisions required before broader implementation. Overall, the findings indicated that the developed RADEC-based Deep Learning Lesson Planning (PPM) demonstrated satisfactory quality in terms of validity, practicality, and preliminary effectiveness within the context of this study. Nevertheless, feedback from experts and the teacher identified several areas requiring refinement, including improvements to the assessment rubrics, adjustment of the learning-objective sequence, clearer instructions for the Read stage, and revision of instructional time allocations to better accommodate the planned learning activities.

In terms of validity, evaluations conducted by language, subject-matter, and instructional-design experts indicated that the PPM met the predetermined criteria across linguistic, content, and instructional-design aspects. Regarding practicality, the user-response questionnaire completed by the classroom teacher yielded a score of 92.85%, categorized as very feasible, suggesting that the developed PPM was generally understandable and applicable in classroom instruction. However, because the practicality evaluation involved only one teacher, this finding represents preliminary evidence and should be further examined with a larger and more diverse group of teachers.

Regarding preliminary effectiveness, the paired-samples t-test showed a statistically significant difference between students' pretest and posttest critical-thinking scores, $t(22) = -10.552$, $p < .001$. The mean N-Gain of approximately 0.56 further indicated a moderate level of improvement in students' critical-thinking performance following the implementation of the RADEC-based PPM. Taken together, these findings suggest that the developed product was associated with improved critical-thinking performance in the participating students. However, because the effectiveness evaluation employed a one-group pretest–posttest design without a comparison group, causal conclusions remain limited. Further evaluation involving larger samples, multiple schools and teachers, and a controlled experimental or quasi-experimental design is therefore required to establish stronger evidence regarding the effectiveness and broader applicability of the developed PPM.

B. Discussion

The findings indicate that students demonstrated a significant improvement in critical-thinking performance following the implementation of RADEC-based Deep Learning Lesson Planning (PPM) in fifth-grade IPAS instruction. The mean score increased from 54.22 on the pretest to 80.22 on the posttest, while the mean N-Gain of 0.5605 represented a moderate level of improvement. These results are consistent with the paired-samples t-test, which identified a statistically significant difference between pretest and posttest scores, $t(22) = -10.552$, $p < .001$. Taken together, the findings provide preliminary evidence that the learning experiences organized through the developed PPM were associated with improved critical-thinking performance. This result is consistent with Amelia et al. (2024), who reported that RADEC-based instruction contributed significantly to the critical-thinking skills of fifth-grade students in science learning.

The observed improvement can be interpreted in relation to the sequential cognitive activities embedded within the RADEC model. During the Read stage, students independently engaged with contextual reading materials and instructional videos before classroom instruction, providing opportunities to establish prior knowledge and identify relevant information. The Answer stage required students to process this information and formulate initial responses independently. These initial ideas were subsequently examined during the Discuss stage, where students compared responses, considered alternative perspectives, and evaluated arguments within their groups. During Explain, students organized and communicated their reasoning while responding to questions and clarification from others. Finally, the Create stage provided opportunities to apply acquired knowledge in generating solutions or products related to the problems being studied. This progression from individual preparation to collaborative examination, explanation, and application may help explain why students demonstrated improvement in critical-thinking performance after the intervention.

The integration of these RADEC stages within PPM is also relevant to the principles of Deep Learning, particularly mindful, meaningful, and joyful learning. The pre-class Read and Answer activities encouraged students to approach classroom learning with initial knowledge and responses rather than encountering the content for the first time during face-to-face instruction. Meanwhile, contextualizing ecosystem and food-chain concepts through garden and marine ecosystems provided opportunities to connect scientific concepts with situations closer to students' experiences, supporting meaningful engagement with the content. The subsequent Discuss, Explain, and Create activities required students to reconsider their initial understanding through interaction, argumentation, and application. Thus, the contribution of the developed PPM lies not merely in adopting the RADEC syntax, but in systematically organizing its stages within a Deep Learning-oriented instructional plan.

The distribution of N-Gain scores provides additional insight into students' improvement. A substantial proportion of students (78.26%) was reported to fall within the moderate N-Gain category, suggesting that improvement was not restricted to only a small number of participants. Nevertheless, this distribution should not be interpreted as evidence that the intervention affected students with different initial ability levels equally, because such a conclusion would require additional subgroup or interaction analyses. The overall pattern is consistent with Setyawan et al. (2023), who found that RADEC integrated with STEAM supported critical-thinking development through a systematic sequence in which students progressed beyond receiving information toward analyzing, discussing, and creating solutions to learning problems.

Analysis at the sub-indicator level revealed that interacting with others showed the greatest improvement. This finding can plausibly be associated with the collaborative and argumentative characteristics of the Discuss, Explain, and Create stages. During Discuss, students compared their initial answers, articulated their reasoning, responded to peers' arguments, and negotiated different interpretations. The Explain stage extended this interaction by requiring students to communicate group conclusions and respond to questions or alternative viewpoints during whole-class discussion. Similarly, Create involved collaborative decision-making when students applied their understanding to generate solutions or products. Collectively, these activities provided repeated opportunities to communicate reasoning, evaluate alternative viewpoints, and revise ideas in response to others. This interpretation is supported by Insani et al. (2025), who reported positive contributions of RADEC to elementary students' critical thinking, particularly in aspects involving interaction and scientific communication.

In contrast, making value judgments demonstrated the smallest improvement, with an N-Gain of 0.186, increasing from 37.7% to 49.0%. Compared with other critical-thinking processes, value judgment may require students to integrate factual evidence with criteria, consequences, social considerations, and competing perspectives before reaching a defensible judgment. Such reasoning may be particularly demanding for elementary students and may require repeated exposure to complex contextual problems rather than a relatively brief instructional intervention. Rofi'ah and Rokhmaniyah (2024) similarly identified higher-level processes involving conclusions and value judgments as challenging aspects of critical thinking among fifth-grade students in IPAS learning. The comparatively small improvement therefore suggests that the current PPM may require additional activities that explicitly scaffold value-based reasoning, such as presenting competing alternatives, requiring students to establish evaluation criteria, compare consequences, justify choices with evidence, and reconsider decisions after encountering alternative perspectives.

These sub-indicator findings also have implications for further refinement of the developed PPM. Although RADEC provides substantial opportunities for discussion and collaborative reasoning, the presence of a learning stage does not necessarily ensure equivalent development across all dimensions of critical thinking. Future revisions could therefore strengthen the alignment between specific RADEC activities and the targeted critical-thinking indicators. For example, the Answer and Discuss stages could incorporate questions requiring students to distinguish evidence from assumptions, while Explain could require explicit justification of conclusions. The Create stage could incorporate ecosystem-related dilemmas in which students must select among alternative solutions and justify their decisions using scientific evidence and clearly defined criteria. Such refinements would make the relationship between instructional activities and the intended critical-thinking constructs more explicit.

Beyond student outcomes, the findings should also be considered together with evidence obtained during the product-development process. Expert evaluation indicated that the PPM met the predetermined validity criteria, while the teacher-response assessment yielded 92.85%, categorized as very feasible. These results suggest that the product was considered appropriate in terms of its content, language, instructional design, and classroom usability. However, teacher feedback also identified a discrepancy between the planned and actual duration of several learning activities. This is particularly relevant because the PPM was initially designed to address limited classroom time by moving the Read and Answer stages to the pre-class phase. The additional time required during implementation indicates that cognitively demanding activities such as discussion, explanation, and creation may require more flexible time allocation than originally anticipated. Consequently, the evaluation of the product should consider not only its instructional potential but also the practical conditions required for sustainable classroom implementation.

Overall, the findings provide preliminary evidence that RADEC-based PPM is a valid and practical instructional product and that its implementation was associated with improved critical-thinking performance in fifth-grade IPAS learning. This finding is broadly consistent with Herianingtyas et al. (2023), who emphasized the potential of systematically structured RADEC-based instructional planning to support meaningful learning experiences and critical-thinking development in elementary education. The present study extends this perspective by integrating the complete RADEC sequence with the principles of mindful, meaningful, and joyful learning within a systematically developed PPM and evaluating the resulting product in terms of validity, practicality, and student performance.

Nevertheless, the findings should be interpreted within the methodological boundaries of the study. The effectiveness evaluation involved only 23 students from one elementary school and employed a one-group pretest–posttest design without a comparison group. Consequently, although the significant pretest–posttest difference and moderate N-Gain demonstrate improvement following the intervention, they cannot establish that the observed change was caused exclusively by the RADEC-based PPM. In addition, practicality was evaluated by only one teacher, limiting the extent to which the usability findings can be generalized to other teachers and instructional settings. Future studies should therefore examine the developed PPM with larger and more diverse samples, involve multiple teachers and schools, and employ controlled experimental or quasi-experimental designs. Such research would provide stronger evidence regarding the effectiveness, practicality, and broader applicability of RADEC-based Deep Learning Lesson Planning in elementary IPAS education.

IV. CONCLUSION

This study developed RADEC-based Deep Learning Lesson Planning (PPM) for fifth-grade IPAS instruction on ecosystems and food chains using the ADDIE model. Expert validation indicated that the developed PPM was highly valid in terms of language, content, and instructional design, while the user evaluation yielded 92.85%, indicating a high level of practicality for classroom implementation. Students' critical-thinking scores increased significantly from pretest to posttest, $t(22) = -10.552$, $p < .001$, with a mean N-Gain of approximately 0.56, representing a moderate level of improvement. Overall, the findings provide preliminary evidence that the developed PPM is a valid and practical instructional product and that its implementation is associated with improved critical-thinking performance. However, given the one-group pretest–posttest design and limited sample, further studies involving larger samples, multiple schools and teachers, and comparison groups are required to establish stronger evidence of its effectiveness and broader applicability.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest, whether financial, professional, or personal, that could have influenced the design, implementation, analysis, interpretation, or reporting of this study.

AUTHOR CONTRIBUTIONS

Andi Rafli *contributed to the conceptualization, research design, development of the RADEC-based Deep Learning Lesson Planning (PPM), instrument development, data collection, data analysis, interpretation of the findings, and preparation of the original manuscript,* ***Atep Sujana*** *contributed to the methodology, supervision, validation, and critical review of the manuscript.* ***Effy Mulyasari*** *contributed to the methodology, and supervision. All authors reviewed and approved the final version of the manuscript and agreed to be accountable for the accuracy and integrity of the work.*

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DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES

The authors declare that generative artificial intelligence (AI) and AI-assisted technologies were used solely to support language refinement and improve the clarity and readability of the manuscript. These technologies were not used to generate research data, conduct statistical analyses, interpret the findings, or formulate scientific conclusions. All AI-assisted content was carefully reviewed, verified, and revised by the authors. The authors take full responsibility for the accuracy, integrity, and final content of the manuscript.

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