Attractive : Innovative Education Journal
Vol. 8 No. 1, March 2026

Development of PETA SITAYA Media Based on Deep Learning Integrated with Tri-Nga in IPAS Learning to Improve Elementary Students' Critical Reasoning

Tri Wulandari [1*] , Banun Havifah Cahyo Khosiyono [1] , Ari Setiawan [1] , Ana Fitrotun Nisa [1]
[1] *Universitas Sarjanawiyata Tamansiswa, Indonesia*

wundlndso@gmail.com*

ARTICLE INFO
Article history:
Received
January 07, 2026
Revised
February 24, 2026
Accepted
March 30, 2026

ABSTRACT

This study addresses the need for innovative learning media to enhance elementary school students' critical reasoning skills in IPAS (Ilmu Pengetahuan Alam dan Sosial) learning. The objectives of this research were: (1) to develop a Deep Learning–based educational game media called PETA SITAYA integrated with the Tri-Nga concept; (2) to determine the feasibility of the developed instruments and product; and (3) to examine the effect of the media on improving students' critical reasoning skills. This study employed a Research and Development (R&D) method using the ADDIE model, consisting of analysis, design, development, implementation, and evaluation stages. The subjects included a limited trial involving 24 students and a wider trial consisting of 29 students in the control class and 29 students in the experimental class. Data were collected through needs analysis questionnaires, expert validation sheets, teacher response questionnaires, and critical reasoning tests in the form of pretest and posttest. The instrument validity test showed 15 valid items (r-count ≥ 0.4044) with a reliability coefficient (Cronbach's Alpha) of 0.704. Since the data were not normally distributed, nonparametric tests were applied. The Wilcoxon Signed Rank test indicated significant differences between pretest and posttest scores in both classes (Sig. 0.000). The Mann–Whitney U test revealed a significant difference between the experimental and control classes (Sig. 0.000), with the experimental class obtaining a higher mean rank. The findings conclude that the Deep Learning–based PETA SITAYA media integrated with Tri-Nga significantly improves students' critical reasoning skills in IPAS learning.

Keywords: PETA SITAYA, Deep Learning, Tri-Nga, IPAS learning, critical reasoning

Journal Homepage https://attractivejournal.com/index.php/aj/

Published by CV. Creative Tugu Pena

INTRODUCTION

The era of the Industrial Revolution 4.0 and Society 5.0 has brought fundamental changes to the education system. The rapid development of information technology, artificial intelligence, and digitalization demands a transformation of learning paradigms—from merely transferring knowledge to strengthening higher-order thinking skills. Twenty-first century education emphasizes the importance of critical thinking, creativity, collaboration, and communication as essential competencies for future generations (Rohmah, 2017). In this context, elementary schools play a strategic role as the foundation for developing students' reasoning abilities and character from an early age.

Critical reasoning ability is one of the main indicators of modern educational quality. Critical reasoning includes the ability to identify problems, analyze cause-and-effect

relationships, evaluate evidence, and construct logical arguments reflectively. In Natural and Social Sciences (IPAS) learning, this ability is highly relevant because IPAS integrates scientific and social approaches to understand life phenomena holistically. Ideally, IPAS learning should provide opportunities for real-world exploration, discussion, and evidence-based problem solving (Margayanti F et al., 2024). However, literacy and reasoning achievements of Indonesian students still face serious challenges. International evaluation results show that from 2000 to 2022 Indonesia consistently ranked among the lowest groups in science literacy (Putri & Sari, 2025). Although there was a ranking increase in 2022, the improvement has not yet reflected substantial progress in reasoning quality (Novia et al., 2020).

This phenomenon is also reflected in the local context of Klaten Regency, particularly among sixth-grade students at SD Negeri 3 Glodogan. Preliminary observations indicate that most students still struggle to answer open-ended questions, explain cause-and-effect processes, and connect IPAS concepts with real-life phenomena. Teachers reported that students tend to rely on memorization and lack confidence when asked to provide logical reasoning. Based on critical reasoning indicators proposed by Ennis (Ardiyanti & Nuroso, 2021), only about 30% of students were able to systematically identify problems and construct arguments. This condition reveals a gap between curriculum demands and classroom practice.

The Merdeka Curriculum through IPAS subjects is actually designed with a transdisciplinary approach aimed at fostering curiosity, scientific thinking, and students' social awareness (Darling-Hammond, 1997). However, classroom implementation is still dominated by conventional methods such as lectures and rote learning. The limited use of adaptive and interactive learning media is one of the inhibiting factors in developing students' critical thinking skills. Therefore, innovative learning media are needed to provide contextual, participatory, and reflective learning experiences.

The advancement of educational technology offers strategic opportunities through the use of digital educational games. Prensky (in Damarjati & Miatun, 2021) states that educational games can increase motivation and cognitive engagement through interactive challenges that encourage decision-making and problem-solving. Furthermore, the integration of artificial intelligence through deep learning approaches allows learning systems to become adaptive—adjusting difficulty levels and providing real-time feedback according to students' abilities. The concept of deep learning in education, rooted in the ideas of Marton and Säljö (1976), emphasizes meaningful understanding and conceptual integration rather than mere memorization (Kiky Zakiya Ramadhani Dalimunte et al., 2024)

However, technology-based innovation alone is not sufficient within the Indonesian educational context, which is deeply rooted in cultural values and character education. Ki Hajar Dewantara's Tri-Nga philosophy—Ngerti (understanding), Ngrasa (internalizing), and Nglakoni (acting)—emphasizes that education must shape independent individuals who understand, internalize, and practice virtuous values (Chuang et al., 2024). Integrating Tri-Nga values into digital learning media is a strategic step to ensure that technological transformation remains aligned with character development.

Previous studies have demonstrated the effectiveness of educational game media in improving learning outcomes. (Anwar F & Pajarianto, 2022) reported significant improvement in learning achievement through HOTS-based media, while (Ainiyah et al., 2025) found that digital games enhance students' motivation and logical thinking skills. (Hasanah & Pujiati, 2025) also emphasized that interactive media combined with metacognitive strategies can improve critical thinking ability. However, these studies generally focus on a single dimension—technology, HOTS, or cognitive strategies—without explicitly integrating local cultural values (Hattie, 2012).

This gap underlies the urgency of the present study. To date, limited research at the elementary level has combined artificial intelligence-based deep learning approaches with the integration of Tri-Nga values into a unified instructional design. This study offers novelty through the development of an educational game media titled "PETA SITAYA" (Petualangan Antariksa Sistem Tata Surya / Space Adventure of the Solar System), designed to be adaptive and character-integrated. The media not only adjusts difficulty levels based on students'

responses but also embeds reflective narratives guiding students through the stages of Ngerti, Ngrasa, and Nglakoni in understanding the solar system (Nurlina, 2023).

Based on this background, this study aims to:

1. Develop the PETA SITAYA learning media based on deep learning integrated with Tri-Nga in sixth-grade IPAS learning;
2. Test the feasibility of the media based on expert validation and user responses;
3. Examine the effectiveness of the media in improving students' critical reasoning abilities.

This research is expected to contribute theoretically to the development of culturally grounded educational technology and practically to provide an adaptive learning media model relevant to 21st-century educational needs and Indonesian national character development.

METHOD

This study employed a Research and Development (R&D) approach aimed at producing an interactive educational game media called "PETA SITAYA" and testing its feasibility and effectiveness in improving elementary students' critical reasoning abilities. R&D was chosen because the study not only tests theoretical assumptions but also systematically designs, validates, revises, and implements a product until it becomes feasible and effective for classroom use (Huang et al., 2025).

The development model used was ADDIE (Analysis, Design, Development, Implementation, Evaluation). This model was selected because it provides systematic and flexible stages suitable for technology-based instructional media development. Each stage was conducted iteratively to allow continuous improvement based on field findings (Kelvin et al., 2025).

This stage identified IPAS learning needs, sixth-grade student characteristics, school infrastructure readiness, and issues related to low critical reasoning ability. Data were obtained through observation, interviews, and student needs questionnaires (Kobi et al., 2023).

The design stage included creating flowcharts, storyboards, UI/UX design, developing a simple adaptive deep learning-based system, and integrating Tri-Nga values (Ngerti, Ngrasa, Nglakoni) into the game scenario.

A prototype was developed and validated by subject matter experts and media experts. Revisions were made based on suggestions and feedback.

Limited trials and field tests were conducted to determine the practicality and effectiveness of the media in improving students' critical reasoning abilities (Mashuri et al., 2024).

Formative evaluation was conducted at each stage, and summative evaluation was carried out at the end to produce a final feasible product.

Time and Place of Research

The research was conducted in the second semester of the 2025/2026 academic year. The analysis and development stages took place from January to March 2026, while limited and field trials were conducted from April to May 2026.

The research locations were:

1. SD Negeri 3 Glodogan, South Klaten District, Klaten Regency (limited trial).
2. SD Negeri 2 Danguran, South Klaten District, Klaten Regency (field test).

Subjects and Sampling Technique

Subjects were selected using purposive sampling, based on considerations relevant to the research objectives.

Participants included:

1. 24 sixth-grade students from SD Negeri 3 Glodogan (limited trial).
2. 29 sixth-grade students from SD Negeri 2 Danguran (field test).
3. Sixth-grade teachers from both schools.
4. Two IPAS subject matter experts and two instructional media experts.

Sixth-grade students were selected due to the relevance of the solar system material in the Merdeka Curriculum and their cognitive readiness at the transition from late concrete operational to formal operational stages.

Trial Design

The effectiveness test used a quasi-experimental one-group pretest-posttest design:

$O_1 - X - O_2$

O_1 = Pretest of critical reasoning ability

X = Treatment (use of PETA SITAYA media)

O_2 = Posttest of critical reasoning ability

Treatment was conducted in 3–4 IPAS learning sessions on the solar system topic.

Data Collection Techniques and Instruments

Observation

Used during needs analysis and implementation to measure engagement and critical thinking indicators.

Interview

Semi-structured interviews with teachers to explore instructional needs and pedagogical impact.

Questionnaire

Four-point Likert scale questionnaires (Strongly Agree, Agree, Disagree, Strongly Disagree) were distributed to experts, teachers, and students.

Test (Pretest–Posttest)

Twenty-five essay questions measuring five aspects of critical thinking:

1. Providing simple explanations
2. Analyzing arguments
3. Drawing conclusions
4. Giving further explanations
5. Organizing strategies and tactics

Validity was tested through expert judgment, and reliability was measured using Cronbach's Alpha.

Documentation

Photos, screenshots, students' work, and field notes.

Data Analysis

Feasibility Analysis

Percentage formula:

Percentage = (Obtained Score / Maximum Score) × 100%

Interpretation:

85–100% = Very Good

70–<85% = Good

55–<70% = Fair

<55% = Poor

Effectiveness Analysis

1. N-Gain score:

   $g \geq 0.70$ = High

   $0.30 \leq g < 0.70$ = Moderate

   $g < 0.30$ = Low
2. Paired-sample t-test at 0.05 significance level.

Qualitative Analysis

Data reduction, data display, and conclusion drawing were used to strengthen quantitative findings and describe students' engagement and character development.

RESULT AND DISCUSSION

1. Description of Critical Reasoning Ability Data

The research results were obtained from the pretest and posttest scores of critical reasoning ability in the control class and the experimental class, each consisting of 29 students.

Based on descriptive statistical analysis, the summary of the data is presented as follows:

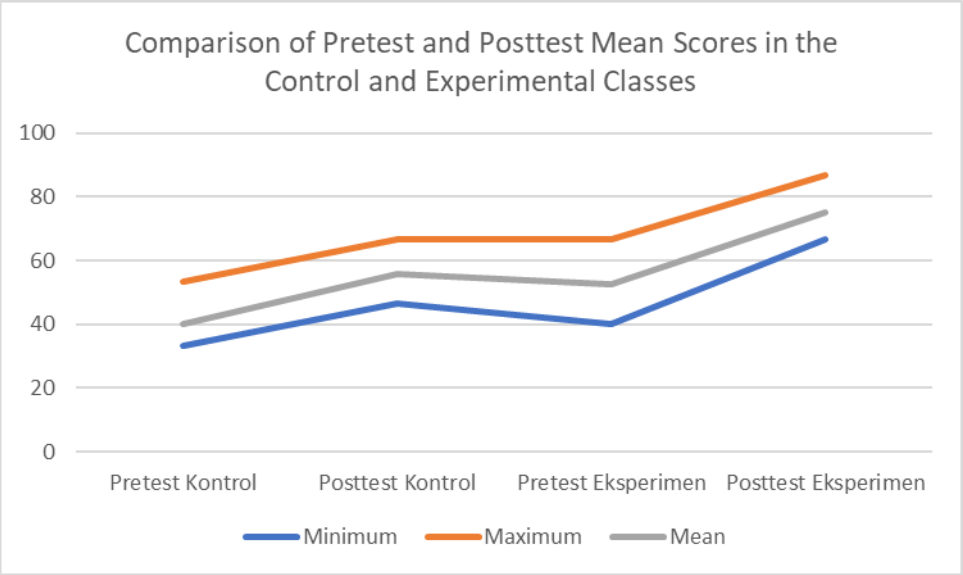
Table 1. Descriptive Statistics of Pretest and Posttest Scores in the Control and Experimental Classes

Class	N	Minimum	Maximum	Mean	Std. Deviation
Control Pretest	29	33.33	53.33	39.99	7.34
Control Posttest	29	46.67	66.67	55.63	7.82
Experimental Pretest	29	40.00	66.67	52.64	8.42
Experimental Posttest	29	66.67	86.67	75.17	7.53

Based on Table 1, the mean score of the control class increased from 39.99 to 55.63. Meanwhile, the experimental class showed an increase from 52.64 to 75.17. The mean gain in the experimental class (22.53 points) was higher than that of the control class (15.64 points).

Visually, the comparison of score improvements can be seen in the following graph.

Figure 1. Comparison of Pretest and Posttest Mean Scores in the Control and Experimental Classes



(Description: The graph shows a more significant increase in the experimental class compared to the control class.)

2. Normality Test

The normality test was conducted using the Shapiro–Wilk test. The results indicate that all datasets had significance values below 0.05.

Table 2. Shapiro–Wilk Normality Test Results

Data	Sig.
Control Class Pretest	0.000
Control Class Posttest	0.000
Experimental Class Pretest	0.006
Experimental Class Posttest	0.001

Since all significance values are less than 0.05, the data are not normally distributed. Therefore, inferential analysis was conducted using non-parametric statistical tests.

3. Homogeneity Test

The homogeneity test using Levene's Test showed a significance value of 0.691 (> 0.05), indicating that the variances of the two groups are homogeneous.

Table 3. Homogeneity Test Results

Levene Statistic	Sig.
0,159	0,691

4. Between-Group Difference Test (Mann–Whitney U Test)

Because the data were not normally distributed, the Mann–Whitney U test was used to determine differences between the control and experimental classes.

Table 4. Mann–Whitney U Test Results

Category	Description
N Control	29
N Experimental	29
Mean Rank Control	16.03
Mean Rank Experimental	42.97
Mann–Whitney U	30.000
Z	-6.177
Asymp. Sig. (2-tailed)	0.000

The significance value of 0.000 < 0.05 indicates a statistically significant difference between the control and experimental classes. The mean rank of the experimental class (42.97) is substantially higher than that of the control class (16.03), meaning that the critical reasoning ability of students in the experimental class is significantly better.

Discussion

Improvement of Critical Reasoning Ability

The findings indicate that the use of PETA SITAYA media based on deep learning integrated with Tri-Nga significantly improved students' critical reasoning ability in IPAS learning. Quantitatively, this improvement is evident from the higher difference between pretest and posttest mean scores in the experimental class compared to the control class. Statistically, the Mann–Whitney test yielded a significance value of 0.000 (<0.05), confirming a significant difference between the two groups. Thus, the treatment in the form of PETA SITAYA media contributed meaningfully to the development of elementary students' critical thinking skills.

Descriptively, the experimental class mean score increased from 52.64 to 75.17, while the control class increased from 39.99 to 55.63. Although both classes showed improvement, the increase in the experimental class was considerably greater. This suggests that systematically designed instructional media can create a more effective learning process compared to conventional teaching methods. The higher score gain in the experimental class indicates not only quantitative improvement but also qualitative enhancement in students' abilities to analyze, evaluate, and conclude information.

Critical reasoning ability in this study included several indicators: providing simple explanations, analyzing arguments, drawing conclusions, giving further explanations, and organizing problem-solving strategies. The PETA SITAYA media was designed to facilitate all five indicators through scenario-based solar system challenges. Students were not merely answering multiple-choice questions; instead, they were required to interpret situations, determine cause-and-effect relationships, and consider alternative solutions before making decisions. This process directly trains higher-order thinking skills (HOTS).

The integration of the Tri-Nga approach (Ngerti – understanding, Ngrasa – internalizing, Nglakoni – applying) was a crucial factor in enhancing media effectiveness. At the Ngerti stage, students gained conceptual understanding of solar system materials through visualization and interactive explanations. At the Ngrasa stage, they were emotionally engaged through challenging gameplay that stimulated curiosity. At the Nglakoni stage, students practiced their knowledge through simulations and mission completion. The combination of these three stages strengthened learning cognitively, affectively, and psychomotorically.

The improvement in critical reasoning ability can also be explained through student engagement theory. Interactive game-based media increases attention and focus by providing

enjoyable and meaningful learning experiences. When students are actively engaged, they process information more deeply. This deep processing characterizes deep learning, which emphasizes comprehensive understanding rather than rote memorization.

Furthermore, the contextual nature of IPAS content supports the use of this media. Solar system topics require visualization and simulation to help students grasp abstract concepts such as rotation, revolution, and planetary relationships. PETA SITAYA provides digital illustrations and interactions that help students construct accurate mental representations. Strong mental representations serve as the foundation for developing critical reasoning skills.

Therefore, the improvement in the experimental class was not coincidental but rather a logical consequence of structured, interactive, and higher-order thinking-oriented instructional design. These findings reinforce the strategic role of innovative learning media in enhancing both the quality of instructional processes and student learning outcomes.

Analysis of Why the Media Had a Significant Effect

The significant impact of PETA SITAYA media can be explained by several interconnected factors.

First, the deep learning approach embedded in the media encouraged students to develop conceptual understanding. Unlike conventional instruction that often emphasizes memorization, PETA SITAYA required students to complete analysis-based missions, compare answer alternatives, and justify their choices logically. This process facilitated stronger meaning construction by connecting new information with prior knowledge.

Deep learning also emphasizes reflection. When students made mistakes, the system provided conceptual feedback explaining why the answer was incorrect. This reflective feedback allowed students to learn from errors and develop more systematic thinking strategies—an essential component of critical reasoning.

Second, the integration of Tri-Nga values added a unique pedagogical dimension. The Ngerti stage ensured conceptual comprehension; the Ngrasa stage fostered emotional engagement through challenges and rewards; and the Nglakoni stage enabled practical application through simulation. This integration ensured that learning extended beyond understanding to meaningful application.

Third, the implementation of game-based learning enhanced intrinsic motivation. Elements such as levels, scores, challenges, and rewards created a healthy competitive atmosphere that motivated students to complete tasks seriously. High intrinsic motivation correlates with persistence in problem-solving, which ultimately enhances critical reasoning ability.

Fourth, the interactive and adaptive features of the media provided personalized learning experiences. The system adjusted difficulty levels according to students' responses. When students performed well, subsequent challenges became more complex; when they struggled, additional assistance was provided. This adaptivity ensured optimal learning opportunities for each student.

Additionally, the use of multimodal representations—text, images, animation, and simulation—supported diverse learning styles and enriched conceptual understanding.

In conclusion, the significant effect of PETA SITAYA was not merely due to technological integration but to a systematic pedagogical design oriented toward higher-order thinking development.

Theoretically, this study strengthens constructivist theory, which asserts that knowledge is actively constructed through interaction with the learning environment. PETA SITAYA provides a digital learning environment where students explore concepts, test hypotheses, and reflect on outcomes.

The study also supports deep learning-based instructional approaches that emphasize conceptual and reflective understanding. Developing critical thinking from an early age is essential in elementary education as a foundation for lifelong learning.

Moreover, the integration of Tri-Nga demonstrates that local educational values can be harmoniously combined with modern technology. Educational innovation does not have to abandon cultural wisdom but can integrate it into contemporary learning frameworks.

Practically, PETA SITAYA can serve as an innovative alternative in elementary IPAS learning. Teachers can use it to explain abstract concepts more concretely while increasing instructional variety.

In the context of the Merdeka Curriculum, which emphasizes competency development and the Pancasila Student Profile, PETA SITAYA is highly relevant as it promotes independence, creativity, and critical thinking skills.

The main findings of this study indicate that PETA SITAYA media is feasible for use based on expert validation results in terms of content, design, interactivity, and suitability for elementary students.

There was a significant improvement in critical reasoning ability in the experimental class after using the media, as evidenced by statistical analysis showing significant differences between pretest and posttest scores.

Additionally, a significant difference was found between the control and experimental classes (Sig. 0.000), indicating that deep learning-based media integrated with Tri-Nga is more effective than conventional instruction.

Overall, this study demonstrates that well-designed instructional media integrated with appropriate pedagogical approaches can enhance the quality of IPAS learning. PETA SITAYA not only improves learning outcomes quantitatively but also strengthens students' critical thinking skills as preparation for 21st-century challenges.

CONCLUSION

Based on the research results and discussion, it can be concluded that the development of PETA SITAYA media based on deep learning integrated with Tri-Nga is effective in improving elementary students' critical reasoning ability in IPAS learning. The media was declared feasible based on expert validation and received positive responses from teachers and students.

Empirically, there was a significant improvement between pretest and posttest scores in the experimental class. The Mann–Whitney test result showed a significance value of 0.000 (<0.05), indicating a significant difference between the control and experimental classes. The experimental class achieved higher posttest mean scores, confirming the positive impact of PETA SITAYA on students' critical reasoning development.

The integration of Tri-Nga (Ngerti, Ngrasa, Nglakoni) and deep learning principles in media design fostered active engagement, deep conceptual understanding, and analytical skills. Therefore, PETA SITAYA represents a relevant instructional innovation to support the development of critical thinking skills in elementary IPAS learning.

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