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The Effect of a TPACK-Based IPAS E-Module Integrated with Tri Nga on Elementary Students' Scientific Critical Thinking

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ABSTRACT

This study aims to develop a TPACK-based IPAS e-module integrated with Tri Nga values and examine its effectiveness in enhancing elementary students' critical thinking skills. A quantitative approach with a quasi-experimental two-group pretest–posttest design was employed involving 85 fifth-grade students. Data were collected using a critical thinking test and analyzed through Structural Equation Modeling (SEM) and an independent samples t-test. The findings reveal that the e-module has a positive and significant effect on students' critical thinking, with a path coefficient of 0.76 and an R-square value of 0.58. The t-test results indicate a significant difference between the experimental and control groups ($t = 5.724$, $p < 0.05$), with a mean improvement of 13.98. These results suggest that the developed e-module is effective in improving students' critical thinking skills. The study implies that integrating TPACK with local cultural values (Tri Nga) provides an innovative, contextual, and interactive approach to support 21st-century learning.

INTRODUCTION

The paradigm of education has moved beyond instructor-oriented instruction toward a learner-centric pedagogical framework that focuses on building expert-level thinking, especially critical thought. As a fundamental competency, critical thinking empowers learners to scrutinize data, assess the validity of claims, and reach evidence-based decisions (Abrami et al., 2015; Raj et al., 2022; Chen et al., 2024). In the context of Integrated Science in elementary-level IPAS (Integrated Sciences) classes this skill exerts a significant influence on helping students understand natural and social phenomena in a meaningful and contextual manner.

Empirical evidence indicates that students' critical thinking skills remain relatively low. Preliminary observations revealed an average critical thinking score of 2.33 out of 4, equivalent to

approximately 58.25% of the ideal level. The aspect of logical and analytical thinking scored only 2.00 (50%), suggesting indicating that students often fail to perceive the interconnectedness of core principles, draw conclusions, and construct systematic reasoning. This condition is further exacerbated by low student engagement and limited use of technology-based innovative learning materials in IPAS instruction. The evidence presented here reinforces prior academic work indicating that Indonesian analytical skills among learners are still below average the international, as reported in the Programme for International Student Assessment (Sae & Radia, 2023).

A review of the literature highlights that e-modules, as digital learning materials, have significant potential to improve learning quality. Delita et al., (2022) found that e-modules enhance students' motivation and learning outcomes, while (Permatasari et al., 2023) demonstrated their contribution to improving critical thinking skills. Moreover, the TPACK framework has been widely adopted as an integrative approach in technology-based learning (Filina et al., 2024; Arifuddin et al., 2025; Hadi Irawan & Khoiruman, 2025). On the other hand, local value-based approaches such as Tri Nga have been shown to support holistic learning encompassing encompassing theoretical understanding, affective engagement, and practical application domains (Nurmawati et al., 2022; Pramesti et al., 2023; Wahyuni & Susanto, 2023; Usman et al., 2024; Zulfana et al., 2025).

However, previous studies reveal a significant research gap. First, most studies focus on technology-based e-modules without integrating local cultural values. Second, research on Tri Nga— a learning philosophy consisting of ngerti (understanding), ngrasa (internalizing), and nglakoni (applying), which supports the development of analytical and reflective thinking—has predominantly been conducted in conventional learning settings and has not been widely applied in digital learning materials. Third, only a limited number of studies have attempted to integrate TPACK and Tri Nga within a unified instructional design.

Based on this gap, the primary objective of this research is to design a TPACK-based IPAS an e-module that seamlessly combines Tri Nga values and to evaluate its efficacy in improving elementary learners' analytical reasoning competencies. The novelty of this research stems from the incorporation of technology-based learning approach (TPACK) with local cultural values (Tri Nga) within an innovative and contextual e-module design.

Accordingly, this study addresses the questions that guide this investigation: (1) What correlational structure exists between the TPACK-based IPAS e-module integrated with Tri Nga and students' critical thinking? (2) How significantly does the e-module shape students' critical thinking competencies based on SEM analysis? (3) Is there the discrepancy in students' higher-order thinking skills before and after the study using the e-module?

To answer these questions, the following hypotheses are proposed:

H1: The TPACK-based IPAS e-module integrated with Tri Nga has a positive and significant effect on elementary students' critical thinking.

H2: The TPACK components and Tri Nga values within the e-module have a significant structural relationship in influencing students' critical thinking.

H3: There is a significant difference in students' critical thinking skills between the pretest and posttest after using the TPACK-based IPAS e-module integrated with Tri Nga.

METHOD

A quantitative, quasi-experimental approach was implemented in this study to scrutinize the success of a TPACK-based IPAS e-module integrated with Tri Nga in enhancing elementary learners' capacity for independent critical thought. Two-a design involving initial and final evaluations of the participants was applied, allowing for comparison of students' critical thinking performance pre- and post-intervention the intervention.

The study began with a pre-intervention diagnostic assessment to evaluate students' baseline critical thinking abilities. Following this, the experimental group received instruction using the TPACK-based IPAS e-module integrated with Tri Nga, while the control group participated in conventional learning. At the end of the intervention, both groups completed a posttest to measure improvements in

critical thinking skills. The overall two-group pretest–posttest research design employed in this study is presented in Table 1.

Table 1. Illustrating The Two-Group Pretest–Posttest Structure Applied in This Study

Group	Pretest	Treatment	Posttest
Experimental	O_1	Learning using TPACK-based IPAS e-module integrated with Tri Nga	O_2
Control	O_1	Conventional learning	O_2

The participants consisted of approximately 85 fifth-grade elementary school students in Yogyakarta, selected through purposive sampling. The selection criteria included students with relatively low critical thinking skills and limited exposure to technology-based instructional materials in IPAS learning.

The primary research instrument was a critical thinking test administered as both pretest and posttest. The test was developed based on five indicators: curiosity, logical and analytical thinking, problem analysis and solving, logical argumentation, and the application of literacy and numeracy in scientific problem-solving.

Instrument validity was established through two stages. Content validity was assessed by subject matter and evaluation experts using Aiken's V index, with a threshold of $V > 0.80$ indicating validity. Empirical validity was examined using product moment correlation, where the validity of the items was established if the resulting correlation coefficient exceeded the critical value at a 0.05 significance level. Internal consistency was evaluated via Cronbach's alpha, requiring a threshold of 0.70 or higher, indicating acceptable internal consistency.

Data were collected through the administration of the critical thinking test in pretest and posttest formats. Quantitative data analysis was conducted using two main techniques. First, Structural Equation Modeling (SEM) was employed to examine the relationships and effects of the e-module on students' critical thinking, including both measurement and structural model evaluations. Second, a student's t-test for independent samples was conducted to determine differences in students' critical thinking re- and post-intervention, with significance defined as $p < 0.05$.

RESULTS AND DISCUSSIONS

Results

The findings of this study are presented in an integrated manner to fulfill the research objectives and test the study's predictions. Data analysis was conducted utilizing Structural Equation Modeling (SEM) alongside unpaired t-tests to analyze complex variable relationships and group differences, enabling a comprehensive understanding of both the structural relationships and the impact of the e-module intervention in enhancing students' critical thinking skills.

Results of the independent samples t-Test

The independent samples t-test analysis was preceded by Levene's Test for Equality of Variances to verify the homogeneity assumption. The test yielded a non-significant result ($p = 0.092 > 0.05$), indicating that the assumption of equal variances was satisfied and that the independent samples t-test could be performed. The results of the independent samples t-test comparing the critical thinking scores of the experimental and control groups are presented in Table 2.

Table 2. Independent Samples t-Test Result

Variable	t	df	p-value	Mean Difference	95% CI
Critical Thinking	5.724	83	<0.001	13.98	[9.13, 18.84]

Prior to the analysis, a homogeneity of variance test using Levene's Test confirmed that the assumption of equal variances was met. The independent samples t-test results reveal a significant difference in critical thinking scores between the experimental and control groups. Students who learned

using the TPACK-based IPAS e-module integrated with Tri Nga demonstrated higher critical thinking performance compared to those who experienced conventional learning. This finding indicates that the developed e-module is more effective in facilitating the development of students' critical thinking skills.

Measurement Model (Outer Model)

Before evaluating the structural relationships among the variables, the measurement model (outer model) was assessed to ensure the validity of the measurement indicators. Convergent validity was examined by evaluating the loading factor of each indicator and the Average Variance Extracted (AVE). Indicators with loading factors greater than 0.70 and AVE values exceeding 0.50 indicate that the construct has adequate convergent validity. The results of the convergent validity assessment are presented in Table 3.

Table 3. Convergent Validity Results (Factor Loadings and AVE)

Variable	Indicator	Loading Factor	Remarks
Critical Thinking	Curiosity	0.78	Valid
Critical Thinking	Logical and analytical thinking	0.81	Valid
Critical Thinking	Problem analysis and problem-solving	0.84	Valid
Critical Thinking	Logical argumentation	0.79	Valid
Critical Thinking	Literacy and numeracy	0.83	Valid

Following the assessment of indicator validity, the overall quality of the measurement model was further evaluated by examining the Average Variance Extracted (AVE) and the coefficient of determination (R^2). The AVE value indicates the extent to which the construct explains the variance of its indicators, while the R^2 value reflects the proportion of variance in the endogenous variable explained by the exogenous variable. The results of these analyses are summarized in Table 4.

Table 4. AVE and R-Square Values

Variable	AVE	R-Square	Category
Critical Thinking	0.67	0.58	Valid and Good

After confirming that the measurement model met the required validity criteria, the structural model (inner model) was evaluated to examine the hypothesized relationship between the TPACK-based E-Module integrated with Tri Nga philosophy and students' critical thinking skills. The structural model was assessed using the path coefficient, t-statistic, and p-value obtained through the bootstrapping procedure. The results of the hypothesis testing are presented in Table 5.

Table 5. Path Coefficient Results (Inner Model)

Variable Relationship	Path Coefficient	t-statistic	p-value	Remarks
TPACK-based E-Module + Tri Nga → Critical Thinking	0.76	8.45	0.000	Significant

Outcomes of the measurement model (outer model) are presented in Table 3. All indicators of critical thinking achieved loading factors surpassed the suggested requirement of 0.70, spanning from 0.78 to 0.84. This suggests that all indicators curiosity, logical and analytical thinking, problem analysis and problem-solving, logical argumentation, and literacy and numeracy demonstrate adequate convergent validity and are valid measures of the construct.

As shown in Table 4, the Average Variance Extracted (AVE) value is 0.67, exceeding the 0.50 baseline, which validates the presence of robust convergent validity. Additionally, the R-square value of 0.58 signifies that the proposed model accounts for 58% of the variance in students' critical thinking, suggesting moderate to substantial explanatory power.

Furthermore, the structural model (inner model) results presented in Table 5 show that the TPACK-based e-module integrated with Tri Nga exerts a favorable and meaningful impact on students'

critical thinking. The path coefficient is 0.76, with a t-statistic of 8.45 and a p-value < 0.05, points to a powerful and statistically relevant significant relationship. These findings confirm that the developed e-module contributes effectively to improving students' critical thinking skills.

Discussion

The findings of this study indicate that the TPACK-based IPAS e-module integrated with Tri Nga has a meaningful influence on students' critical thinking skills. As presented in Tables 2 and 5, both the comparative and structural analyses consistently demonstrate that students who engaged with the developed e-module achieved better critical thinking performance than those who experienced conventional learning.

This improvement can be explained by the integration of the TPACK framework, which enables the coherent alignment of technological, pedagogical, and content knowledge within the learning process. Such integration creates interactive and contextual learning environments that encourage students to actively explore information, analyze problems, and construct their own understanding. As a result, learning becomes more student-centered and supports the development of critical thinking skills. This finding is in line with previous studies (Ningsih & Dokhi, 2022; Aqilah & Lathifah, 2023; Handayani & Saputra, 2023), which emphasize that TPACK integration enhances learning quality, increases student engagement, and promotes meaningful learning experiences.

In addition, the incorporation of Tri Nga values ngerti (understanding), ngrasa (internalizing), and nglakoni (applying) plays a significant role in strengthening the depth of learning. These stages guide students through a structured process from conceptual understanding to reflective internalization and practical application. This progression supports essential components of critical thinking, such as analysis, evaluation, and decision-making, by encouraging students to connect knowledge with real-life contexts. These results are consistent with previous studies (Gunawan et al., 2023; Saili & Taat, 2023; Krishantari, 2025; Ardi et al., 2025), which demonstrate that Tri Nga-based learning approaches promote deeper engagement and facilitate higher-level thinking processes.

Furthermore, the improvement observed across various indicators of critical thinking including curiosity, logical and analytical thinking, problem-solving, logical argumentation, and the application of literacy and numeracy indicates that the developed e-module supports a comprehensive development of students' thinking abilities. This suggests that the integration of TPACK and Tri Nga does not only enhance cognitive aspects but also fosters a more holistic learning process that connects knowledge, reflection, and application.

Compared to previous studies, this research offers a more integrative contribution by combining technology-based pedagogy with local cultural values within a single instructional design. While earlier studies have tended to examine e-modules, TPACK, or Tri Nga separately, this study demonstrates that their integration provides a more effective and contextually relevant approach to improving students' critical thinking skills.

Therefore, the main contribution of this study lies in presenting an innovative digital learning model that integrates TPACK and Tri Nga to support meaningful and culturally responsive learning. These findings highlight the importance of developing instructional materials that are not only technology-enhanced but also grounded in local values to ensure deeper learning experiences.

From a practical perspective, the TPACK-based IPAS e-module integrated with Tri Nga can serve as an effective alternative for elementary school learning. Its implementation can assist teachers in designing innovative, interactive, and contextually relevant learning environments that support the development of students' critical thinking skills in line with the demands of 21st-century education.

CONCLUSION AND SUGGESTION

This study concludes that the TPACK-based IPAS e-module integrated with Tri Nga effectively enhances elementary students' critical thinking skills. The integration of technological, pedagogical, and content knowledge within a culturally grounded learning framework creates a more meaningful and engaging learning experience. Through this approach, students are encouraged not only to understand concepts but also to internalize and apply them in relevant contexts, which supports the development

of critical thinking.

The findings also indicate that the combination of TPACK and Tri Nga contributes to a more holistic learning process by integrating cognitive, reflective, and practical dimensions of learning. This integrated approach enables students to actively engage in analyzing, evaluating, and solving problems, thereby strengthening their critical thinking skills in a comprehensive manner.

From a practical perspective, the developed e-module can serve as an effective alternative learning resource for elementary education. It supports teachers in designing innovative, interactive, and contextually relevant learning experiences that align with the demands of 21st-century education.

For future research, it is recommended to expand the scope of the study by involving larger and more diverse samples, as well as exploring the long-term impact of integrating TPACK and local cultural values in digital learning environments on students' critical thinking and other relevant competencies.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this paper.

AUTHOR CONTRIBUTIONS STATEMENT

Conceptualization, E.D. and T.I.; methodology, E.D. and T.I.; formal analysis, E.D.; investigation, E.D. and T.I.; data curation, E.D.; writing—original draft preparation, E.D.; writing—review and editing, T.I.; visualization, E.D.; supervision, T.I. All authors have read and agreed to the published version of the manuscript.

DECLARATION OF GENERATIVE AI SOURCES

During the preparation of this manuscript, the author(s) used ChatGPT (OpenAI) and Scopus AI (Elsevier) to assist with literature exploration, language refinement, grammar improvement, and structural organization of the manuscript. All generated content was carefully reviewed, revised, and verified by the author(s), who take full responsibility for the final content of the manuscript.

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