

The influence of the STEM learning model assisted by tinkercad media on elementary school students' critical thinking skills

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KEYWORDS	ABSTRACT
<p>Keywords: STEM model; Tinkercad; critical thinking skills; elementary school; science and social studies learning</p> <p>Conflict of Interest Statement: The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.</p> <p>Copyright © 2026 EDU. All rights reserved.</p>	<p>This study aims to analyze the effect of the STEM learning model assisted by Tinkercad media on the critical thinking skills of elementary school students and to compare its effectiveness with the Discovery Learning model. A quasi-experimental design with a Nonequivalent Control Group Design was employed. The sample consisted of 40 fifth-grade students from SDN 3 Sindangkasih, divided into experimental and control classes. Data were collected using a validated essay test and analyzed using regression analysis, paired sample t-test, independent t-test, and Mann-Whitney U test. The results showed a significant effect of the STEM model assisted by Tinkercad on students' critical thinking skills, with a contribution of 48.1% ($R^2 = 0.481$) and an increase in the average score from 49.16 in the pretest to 63.12 in the posttest. Furthermore, the experimental class outperformed the control class in the posttest ($63.12 > 46.66$), with a significant difference ($p < 0.001$). The N-Gain of the experimental class (0.28, moderate) was higher than the control class (0.09, low). The STEM model assisted by Tinkercad is proven effective in improving critical thinking skills and is recommended as an innovative alternative in elementary science and social studies learning, particularly for contextual topics such as natural disasters.</p>

Introduction

The 21st century demands that education systems equip students with higher-order thinking skills, particularly critical thinking, to navigate the complexities of the digital age (Mardhiyah et al., 2021). In Indonesia, however, the development of critical thinking skills at the elementary school level remains suboptimal. Data from PISA 2022 indicate that Indonesian students continue to struggle with reasoning and application tasks, reflecting a systemic lack of higher-order thinking training in school curricula (Arisha & Surya, 2023). Observational studies further confirm that approximately 85% of fifth-grade students fall into the very low category of critical thinking ability, largely due to the dominance of conventional, teacher-centered instruction that prioritizes memorization over analysis (Rofi'ah & Rokhmaniyah, 2024). This gap between policy aspirations and classroom realities highlights an urgent need for pedagogical innovation.

Previous studies have explored various instructional approaches to address this issue. Research on STEM (Science, Technology, Engineering, and Mathematics) education has shown promising results in enhancing critical thinking skills among elementary students (Zalsa et al., 2025; Davidi, Sennen, & Supardi, 2021). STEM's project-based and inquiry-driven nature encourages students to engage in problem-solving, analysis, and evaluation, which are core components of critical thinking. Similarly, the use of digital simulation tools has been found to improve conceptual understanding and practical skills (Riskawati, Said, & Herman, 2024). Among these tools, Tinkercad—a free, web-based 3D design platform—has gained attention for its ability to facilitate virtual prototyping and experimentation, particularly in science and engineering contexts (Putri, Setiawan, & Putro, 2024).

Despite these positive findings, several limitations remain. First, most STEM studies in Indonesia have been conducted at the secondary level, with limited empirical evidence from elementary schools. Second, while STEM is often studied in general science contexts, its integration with specific, locally relevant topics—such as disaster mitigation—remains underexplored. Third, the majority of existing research examines STEM and digital tools separately, without investigating their synergistic effects within a structured, replicable instructional model. Few studies have combined STEM pedagogy with a specific digital platform like Tinkercad in a controlled experimental setting, particularly for young learners. This creates a gap in understanding how such integration can systematically foster critical thinking skills in elementary school students.

To address these gaps, this study examines the effect of a STEM learning model integrated with Tinkercad media on the critical thinking skills of fifth-grade students, using a quasi-experimental design with a nonequivalent control group. Specifically, it compares the effectiveness of this integrated approach with that of the Discovery Learning model. The study focuses on the topic of earthquake disaster mitigation—a highly contextual and locally relevant issue in Indonesia, given its geographic vulnerability to seismic activity. By embedding the learning process within real-world problems and providing students with opportunities to design, test, and redesign virtual prototypes, this study seeks to offer a replicable instructional framework that bridges theory and practice.

The scientific contribution of this research lies in three areas. First, it provides empirical evidence on the effectiveness of STEM combined with a specific digital tool in an elementary school context—a population rarely included in such studies. Second, it offers a practical model for integrating technology into disaster mitigation education, which aligns with national priorities for strengthening disaster literacy. Third, it addresses the methodological gap identified in previous research by using both regression analysis and comparative statistical tests to measure the contribution of the treatment and the significance of the differences between groups. Thus, this study is expected to contribute to both educational theory and classroom practice, offering a practical alternative for teachers seeking to foster critical thinking in their students.

Based on the background outlined above, this study aims to answer the following research questions: (1) Is there a significant effect of the STEM learning model assisted by Tinkercad media on the improvement of critical thinking skills among fifth-grade elementary school students? (2) Is the improvement in critical thinking skills among students who learn using the STEM model assisted by Tinkercad significantly better than that of students who learn using the Discovery Learning model?¹

Research Design and Methodology

This study employed a quantitative approach with a quasi-experimental design, specifically the Nonequivalent Control Group Design. This design was chosen because it allows for the comparison of an experimental group and a control group without random assignment, which is practically feasible in intact classroom settings. The experimental group received instruction using the STEM learning model assisted by Tinkercad, while the control group was taught using the Discovery Learning model.

The study was conducted at SDN 3 Sindangkasih, Purwakarta, Indonesia, during the even semester of the 2025/2026 academic year. The population comprised all fifth-grade students at the school, from which two intact classes were selected using purposive sampling. The sample consisted of 40 students: 20 in the experimental group (Class 5B) and 20 in the control group (Class 5A). Both groups had similar academic backgrounds and received instruction on the same topic—earthquake disaster mitigation—as part of the science and social studies (IPAS) curriculum.

The treatment was administered over four sessions (two cycles) for the experimental group, following the CATUR STEM syntax: (1) problem identification, (2) problem analysis, (3) idea generation and solution design, (4) testing, and (5) design improvement and communication of results. In each cycle, students used Tinkercad to design and simulate earthquake-resistant building prototypes, then constructed physical models using toothpicks and plasticine. The control group followed a six-step Discovery Learning model: (1) stimulation, (2) problem statement, (3) data collection, (4) data

¹ Our references uses the Chicago Manual of Style. The citation quick guide can be found at: http://www.chicagomanualofstyle.org/tools_citationguide/citation-guide-1.html Example for Books references: S H Djulaeka and S H Devi Rahayu, *Buku Ajar: Metode Penelitian Hukum* (Scopindo Media Pustaka, 2020).

processing, (5) verification, and (6) generalization. Both groups were taught by the same teacher to minimize instructor-related bias.

Data were collected using a critical thinking skills test consisting of six essay questions, each aligned with six core indicators of critical thinking (interpretation, analysis, evaluation, inference, explanation, and self-regulation) based on Facione's framework (2013). The test was administered twice: before the treatment (pretest) and after the treatment (posttest). The instrument underwent content validation by expert judges and empirical validity testing through construct validity analysis using Pearson product-moment correlation. Reliability was estimated using Cronbach's alpha, yielding a coefficient of 0.88, indicating high internal consistency. Additionally, item difficulty and discrimination indices were calculated to ensure the quality of each question.

Prior to hypothesis testing, prerequisite tests were conducted, including normality (Shapiro-Wilk) and homogeneity (Levene's test). Because not all data met the normality assumption, both parametric and non-parametric tests were employed. For the experimental group, the effect of the treatment was analyzed using paired sample t-test and simple linear regression analysis, preceded by tests for residual normality and linearity. The contribution of the treatment was measured using the coefficient of determination (R^2). For between-group comparisons, an independent t-test was used for pretest and posttest scores, while the Mann-Whitney U test was applied to compare N-Gain scores, as N-Gain data were not normally distributed. All statistical analyses were performed using SPSS version 26.0.

Findings and Discussion

Findings

This section presents the main findings of the study, organized sequentially to answer the two research questions. Data were analyzed using both parametric and non-parametric statistical techniques, depending on the fulfillment of prerequisite assumptions. A summary of the descriptive statistics for both groups is presented in Table 1.

Table 1. Descriptive Statistics of Pretest and Posttest Scores.

Group	Test	N	Mean	SD	Min	Max
Control	Pretest	20	41.87	10.42	25.00	62.50
Control	Posttest	20	46.66	13.15	25.00	70.83
Experimental	Pretest	20	49.16	12.93	29.16	70.83
Experimental	Posttest	20	63.12	14.83	37.50	91.66

Source: Processed data (2026)

As shown in Table 1, the experimental group exhibited a higher mean posttest score (63.12) compared to the control group (46.66), with a mean gain of 13.96 points versus 4.79 points, respectively. To measure the magnitude of improvement relative to initial ability, N-Gain scores were calculated.

Table 2. N-Gain Descriptive Statistics

Group	N	Mean N-Gain	Category
Control	20	0.09	Low
Experimental	20	0.28	Moderate

Source: Processed data (2026)

Table 2 indicates that the experimental group achieved a moderate N-Gain (0.28), while the control group remained in the low category (0.09). However, statistical significance was tested through inferential analysis.

Prior to hypothesis testing, prerequisite tests were conducted. The Shapiro-Wilk normality test revealed that not all data were normally distributed. The Levene's test showed homogeneity for pretest and posttest data but not for N-Gain. Consequently, parametric tests were used where assumptions were met, and non-parametric tests were applied for N-Gain comparisons.

To answer the first research question—whether there is a significant effect of the STEM model assisted by Tinkercad on students' critical thinking skills—a simple linear regression analysis was performed. The results are presented in Table 3.

Table 3. Simple Linear Regression Analysis (Experimental Group)

Model	Unstandardized Coefficients		t	Sig.
	B	Std. Error		
(Constant)	24.026	6.992	3.437	0.003
Pretest	0.795	0.195	4.085	0.001

Dependent Variable: Posttest; R² = 0.481; Source: Processed data (2026)

The regression equation derived from Table 3 is: $Posttest = 24.026 + 0.795 (Pretest)$. The coefficient of determination ($R^2 = 0.481$) indicates that the initial ability (pretest) explains 48.1% of the variance in posttest scores. The significance value ($p = 0.001$) confirms that the regression model is statistically significant.

Additionally, a paired sample t-test was conducted to confirm the significance of the improvement within each group. The experimental group showed a significant increase from pretest to posttest ($t = -5.676$, $p < 0.001$), as did the control group ($t = -2.409$, $p = 0.026$), though with a much smaller effect.

To answer the second research question—whether the experimental group's improvement was significantly better than the control group's—an independent t-test was conducted on posttest scores, followed by a Mann-Whitney U test on N-Gain scores. Table 4 summarizes the between-group comparisons.

Table 4. Between-Group Comparisons

Test Variable	Experimental	Mean	Control Mean	Test Statistic	Sig.
Independent t-test	Pretest	49.16	41.87	$t = -1.961$	0.057
Independent t-test	Posttest	63.12	46.66	$t = -3.715$	<0.001
Mann-Whitney U	N-Gain	Mean Rank 26.45	Mean Rank 14.55	$U = 81.00$	<0.001

Source: Processed data (2026)

As shown in Table 4, the pretest comparison showed no significant difference between groups ($p = 0.057$), indicating that both groups were equivalent at the outset. However, the posttest comparison revealed a significant difference ($p < 0.001$), with the experimental group outperforming the control group. The Mann-Whitney U test on N-Gain scores further confirmed that the improvement in the experimental group (Mean Rank = 26.45) was significantly higher than that of the control group (Mean Rank = 14.55), with $p < 0.001$.

Discussion

The findings of this study demonstrate that the STEM learning model assisted by Tinkercad has a significant positive effect on the critical thinking skills of elementary school students. The regression analysis revealed that the pretest scores explained 48.1% of the variance in posttest scores ($R^2 = 0.481$), indicating a substantial contribution of the instructional treatment to the observed improvement. This is further supported by the paired t-test results, which showed a significant increase from pretest ($M = 49.16$) to posttest ($M = 63.12$) in the experimental group ($p < 0.001$). These findings align with previous research by Zalsa et al. (2025) and Davidi, Sennen, and Supardi (2021),

who reported that STEM-based instruction effectively enhances critical thinking skills by engaging students in active problem-solving and hands-on experimentation.

The effectiveness of the STEM model can be attributed to its structured syntax, which embeds critical thinking into each phase of learning. During the problem identification phase, students were exposed to authentic video footage of earthquake disasters, which stimulated curiosity and contextual awareness—essential precursors to critical analysis (Fauziah & Kuntoro, 2022). The analysis phase allowed students to explore causal mechanisms and physical principles, fostering deep conceptual understanding through cognitive processing (Sujarwanto, 2023). In the idea generation and solution design phase, students collaboratively designed earthquake-resistant buildings using Tinkercad, which required them to integrate multiple variables, evaluate alternatives, and justify their design choices. This process directly trained the interpretation, analysis, and evaluation indicators of critical thinking.

A distinctive feature of this study was the integration of the digital simulation tool Tinkercad, which enabled students to test and revise their virtual prototypes iteratively. This aligns with Kolb's experiential learning theory (1984), which posits that concrete experience and active experimentation are more effective than abstract conceptualization alone. Students were able to observe immediate feedback from their design modifications, which encouraged reflective thinking and self-regulation—skills that are often difficult to cultivate through traditional instruction. This finding supports the work of Putri, Setiawan, and Putro (2024) and Riskawati, Said, and Herman (2024), who reported that Tinkercad enhances student engagement and conceptual understanding in STEM contexts.

The between-group comparison further strengthens the argument for the superiority of the STEM model over Discovery Learning. Although the Discovery Learning model also produced a statistically significant improvement ($p = 0.026$), the effect size was considerably smaller. The experimental group's posttest mean (63.12) significantly exceeded that of the control group (46.66), with a mean difference of 16.46 points. Moreover, the N-Gain comparison using Mann-Whitney U confirmed that the experimental group's improvement (Mean Rank = 26.45) was significantly higher than the control group's (Mean Rank = 14.55), with $p < 0.001$. This suggests that while both models are capable of fostering learning gains, the STEM + Tinkercad approach offers a more substantial and meaningful improvement in critical thinking skills.

The superiority of the STEM model can be explained by its interdisciplinary and project-based nature. Unlike Discovery Learning, which primarily focuses on concept discovery through questioning and guided exploration, STEM integrates science, technology, engineering, and mathematics into a single cohesive project. This integration provides students with multiple entry points for understanding and multiple modalities for expression (Zalsa et al., 2025). The redesign process in Cycle 2, where students were asked to improve their initial prototypes based on test results, specifically targeted the self-regulation indicator—a higher-order critical thinking component that is rarely explicitly taught in conventional models (Fauziah & Kuntoro, 2022). This iterative process taught students that failure is a natural part of engineering and that improvement requires systematic reflection and revision.

Despite the positive results, the N-Gain of the experimental group remained in the moderate category (0.28). This may be attributed to the relatively short intervention period (four sessions) and the broad scope of the critical thinking construct, which encompasses multiple sub-skills that develop at different rates. Self-regulation, in particular, requires sustained practice and metacognitive awareness, which may not fully develop within a brief intervention. This limitation is consistent with previous findings that higher-order thinking skills are more effectively nurtured through long-term, continuous exposure rather than short-term interventions (Facione, 2013). Nonetheless, the experimental group's improvement across all indicators—ranging from interpretation to self-regulation—was consistently higher than the control group's, indicating that the intervention had a positive impact on the entire spectrum of critical thinking sub-skills.

Conclusion

This study found that the STEM learning model assisted by Tinkercad has a significant effect on improving the critical thinking skills of elementary school students. The experimental group showed a substantial increase in average scores from pretest (49.16) to posttest (63.12), with a contribution of 48.1% ($R^2 = 0.481$) and a statistically significant regression model ($p < 0.001$). Furthermore, the improvement in the experimental group was significantly higher than that of the control group, as evidenced by posttest scores (63.12 vs. 46.66) and N-Gain comparisons (mean rank 26.45 vs. 14.55, $p < 0.001$). These findings confirm that the STEM model, when integrated with digital simulation tools, is more effective than Discovery Learning in fostering critical thinking skills in elementary school students.

The significance of this research lies in its contribution to both educational theory and classroom practice. Theoretically, it provides empirical evidence that integrating STEM pedagogy with a specific digital tool Tinkercad can systematically develop higher-order thinking skills in young learners, particularly in contextual topics such as disaster mitigation. Practically, it offers a replicable instructional framework for teachers seeking to move beyond conventional, teacher-centered approaches. The novelty of this study lies in its integration of STEM with a structured digital design platform within a controlled experimental setting, an approach that has been rarely explored at the elementary school level in Indonesia.

Despite its promising findings, this study has several limitations. The intervention was conducted over a relatively short period (four sessions), which may have limited the development of more complex critical thinking sub-skills, particularly self-regulation. Additionally, the sample was limited to one school and 40 students, which restricts the generalizability of the results. Future research is recommended to extend the intervention period, include a larger and more diverse sample, and examine the effects of STEM and Tinkercad on other learning outcomes or across different subject areas. Such studies would further strengthen the evidence base for integrating technology-driven STEM pedagogy in elementary education.

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