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Influence of Multiplication Domino Cards on Critical Thinking Skills in Multiplication Material

Intan Firdaus[1*], Wahyu Maulida Lestari[1], Duhwi Indartiningsih[1], Fakhrur Rozy[1], Ana Christanti[1]

[1]Elementary School Teacher Education Study Program, Faculty of Teacher Training and Education, Universitas Nahdlatul Ulama Sidoarjo

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ABSTRACT

The low critical thinking skills of elementary school students in multiplication require serious attention, as reflected in Indonesia's below-OECD-average mathematics performance in PISA 2022 and the difficulties experienced by fifth-grade students at SDN Pucang IV Sidoarjo in understanding multiplication concepts due to teacher-centered learning and limited use of concrete media. This study examined the effect of multiplication domino cards on fifth-grade students' critical thinking skills using a quantitative pre-experimental one-group pretest-posttest design. The participants were 24 Grade VB students selected through purposive sampling. The treatment was conducted in two meetings through card-matching activities, group discussions, worksheets, and presentations. Critical thinking was measured using 10 open-ended questions based on Facione's indicators of interpretation, analysis, evaluation, and inference. The instrument was valid (r count > r table = 0.455) and reliable (Cronbach's Alpha = 0.952). Data were analyzed using the Shapiro-Wilk normality test and Paired Samples t-Test. The results showed an average pretest of 59.63 increased to 81.88 in the posttest, with the results of the hypothesis test $t(23) = -21.137$, $p < 0.001$, and an effect size (Cohen's id) of 4.31 (very large category). These findings indicate a significant difference in critical thinking abilities in the groups studied after the use of multiplication domino cards media, although the design without a control group does not allow for causal conclusions to be drawn. The results of this study can be a recommendation for teachers to utilize card-based game media as an alternative for learning multiplication, as well as the need for further research with a control group experimental design.

Corresponding Author:

Intan Firdaus,
Elementary School Teacher Education Study Program,
Faculty of Teacher Training and Education,
Universitas Nahdlatul Ulama Sidoarjo
Jl. Raya Lingkar Timur KM 5.5, Rangkah Kidul, Sidoarjo 61234, Indonesia
✉ firdausintan07@gmail.com

Introduction

Mathematics learning in elementary schools is not solely aimed at developing procedural fluency and calculation accuracy. It also needs to provide students with opportunities to understand information, reason about mathematical relationships, evaluate solutions, and justify their conclusions. These skills are crucial so that students are not only able to obtain numerical answers but also to apply mathematical knowledge meaningfully when facing non-routine problems. The urgency of strengthening mathematical reasoning and problem-solving is also reflected in the results of the Programme for International Student Assessment (PISA). In PISA 2022, Indonesia's average mathematics score was recorded at 366, lower than the 2018 PISA score of 379 and below the OECD average. Although PISA data cannot be used to directly describe students' critical thinking skills in a particular grade, the assessment emphasizes the ability to use mathematical knowledge and skills to address complex problems and real-life situations. Therefore, mathematics learning needs to be designed through tasks that provide space for students to reason, choose strategies, compare solutions, and provide justification.

Critical thinking skills in mathematics are not only related to the ability to obtain correct answers, but also include the ability to understand problem conditions, analyze relationships between information, evaluate the accuracy of strategies or solutions, and draw conclusions based on mathematical evidence. Critical thinking skills are part of higher-order thinking skills that enable students to analyze, evaluate, and make logical decisions in solving problems (Asriningtyas et al., 2018; Irawan & Kencanawaty, 2016; Saputra, 2020). In the context of mathematics, critical thinking involves the use of reasoning and cognitive strategies to evaluate unfamiliar situations or problems reflectively (Glazer, in Syahbana, 2012). This study uses four indicators of critical thinking adapted from Facione, namely interpretation, analysis, evaluation, and inference (in Indartiningsih et al., 2025). These four indicators were chosen because they can be directly operationalized in multiplication activities, namely understanding the information and requirements of the problem, analyzing the relationship between factors and products, assessing the accuracy of solutions or strategies, and formulating conclusions or other valid solution possibilities. The use of these indicators is also in line with several studies that examine mathematical critical thinking through the aspects of problem understanding, strategy analysis, answer evaluation, and conclusion drawing (Samudra et al., 2025; Faizah et al., 2024; Wahyuni & Kusaeri, 2024).

However, multiplication learning in elementary schools is still often carried out through routine exercises that emphasize memorizing multiplication facts, using a single procedure, and finding a single, predetermined numerical answer. Initial observations in fifth-grade students at SDN Pucang IV Sidoarjo showed that students still experienced difficulties in understanding multiplication material, lacked confidence when solving problems, and did not receive adequate opportunities to discuss strategies or evaluate answers. The learning process also remained teacher-centered and did not utilize learning media optimally. This situation has the potential to limit students' active involvement in exploring ideas, comparing strategies, and constructing mathematical reasoning. Learning that only positions students as recipients of information can reduce their opportunities to develop independent reasoning and critical thinking (Wiryana & Alim, 2023).

One approach that can be used to expand students' thinking opportunities is through open-ended multiplication tasks. In this study, open-ended multiplication is defined as a multiplication task that allows for more than one valid pair of factors, representations, or solution strategies, while maintaining clear criteria for mathematical correctness. Open-ended tasks do not mean that all answers are acceptable, but rather that students can generate multiple possible answers or solutions that are mathematically justifiable. For example, students can be

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asked to find several forms of multiplication that yield a certain value, compare two strategies for obtaining the same product, or assess whether a solution proposed by a peer is supported by adequate reasoning. Such tasks have the potential to encourage students to analyze the relationship between factors and products, evaluate the validity of strategies, and deduce other possible solutions. The use of problems that require reasoning, diverse strategies, and justification processes is also relevant to the development of higher-order thinking skills in mathematics learning (Fauzi & Abidin, 2019; Febrianti et al., 2021).

To present open-ended multiplication tasks in an engaging manner and actively engage students, learning media are needed that not only serve as visual aids but also as a means of organizing mathematical activities and interactions between students. Learning media is a means of conveying messages that can help students understand material more concretely and meaningfully (Ekayani, 2017). Furthermore, the use of appropriate media can increase student motivation and active involvement in learning (Fadilah et al., 2023; Karo-Karo & Rohani, 2018). One potential medium is multiplication domino cards. In general, multiplication domino cards are cards consisting of two parts: one containing the problem or multiplication expression and the other containing the answer or corresponding representation (Rochmiyatun, 2023). In this study, domino cards are not only used to match multiplication problems with one numerical answer, but are designed as a medium for open-ended multiplication tasks that invite students to discover, compare, evaluate, and explain the relationships between mathematical ideas.

The use of dominoes in mathematics learning has the potential to create a playful learning atmosphere that can support memory, conceptual understanding, numeracy skills, and student engagement (Hamidah & Susanti, 2025). However, the pedagogical value of game media does not lie solely in its fun element. The potential of game media to support learning depends on the quality of the mathematical tasks presented, the activity rules used, the form of interaction between students, and the teacher's role in encouraging discussion, reflective questioning, and providing reasoning. Thus, the multiplication domino cards in this study are positioned not merely as a game tool, but as a pedagogical artifact designed to facilitate students in constructing, comparing, and justifying mathematical ideas. This approach aligns with the use of simulative game-based media to strengthen students' thinking skills (Lestari, 2023).

Several previous studies have shown that multiplication domino cards have the potential to support mathematics learning in elementary schools. Angraeni (2024) found that the use of multiplication domino cards impacted the cognitive learning outcomes of elementary school students. Hamidah and Susanti (2025) also reported that the use of similar media can improve mathematics learning achievement in second-grade students. Furthermore, Rofiqoh et al. (2025) reported an increase in critical thinking skills scores of second-grade students at SDN Mandala 1, from an average pretest score of 36.6 to an average posttest score of 71.6 after learning using domino cards. Other studies have also shown that interactive media for multiplication materials, such as Powtoon (Aliyah & Purwanto, 2022) and the make-a-match model (Putri & Pranata, 2022), can support students' mathematics learning outcomes.

However, these studies generally focus on cognitive learning outcomes, academic achievement, or overall score improvement. Furthermore, many studies use multiplication dominoes to match multiplication expressions with predetermined numerical results. This design is useful for practicing computational fluency, but it fails to adequately explain how domino-based activities can provide space for students to interpret task conditions, analyze mathematical relationships, compare alternative strategies, evaluate the validity of solutions, and provide justification. In other words, empirical evidence regarding the use of dominoes as a medium to support mathematical critical thinking through open-ended multiplication tasks is still limited.

This study attempts to fill this gap by designing a multiplication domino card media based on open-ended multiplication tasks. The contribution of this study lies not only in the use of domino cards as a game medium, but primarily in changing the character of the tasks presented in it. The cards are designed to enable students to generate several possible answers, use various strategies or representations, compare solutions, and provide reasons for the chosen answer. Thus, the multiplication domino card media with an open-ended multiplication concept is expected to provide a relevant learning context for observing students' abilities in interpreting, analyzing, evaluating, and inferring multiplication material. Based on this description, this study aims to analyze the effect of the multiplication domino card media on the mathematical critical thinking skills of fifth-grade students at SDN Pucang IV Sidoarjo before and after participating in learning using the multiplication domino card media with an open-ended multiplication concept. The study used a single-group pretest–posttest design without a comparison group. Therefore, the research results are interpreted as changes in critical thinking ability scores in the group of students studied in a particular learning context, not as evidence of a causal relationship or an estimate of the causal effect of the multiplication domino card media separately from other factors.

Method

Type of Research

The approach used in this study was quantitative with a pre-experimental approach, adopting a One-Group Pretest-Posttest Design. This design was chosen based on the research objective of uncovering differences in critical thinking abilities among a group of subjects observed under controlled conditions, without a comparison group (Sugiyono, 2023; Nurhapitasari et al., 2024). The procedure began with a pretest administered to students before they received treatment using multiplication domino cards, followed by a posttest after the treatment phase was completed. The comparison between the pretest and posttest scores then served as the primary reference for assessing changes in critical thinking abilities among the subject groups studied. A more complete overview of this research design is presented in Table 1.

Table 1. Research Design iOne-group Pretest-Posttest Design

Pretest	Treatment	Posttest
O1	X	O2

Source: Khoirunnissa et al. (2024). Description: O1 = pretest; X = multiplication domino card media treatment; O2 = posttest.

The independent variable is the multiplication domino card media (X); the dependent variable is the students' critical thinking ability on the multiplication material (Y).

Participants

This study took place at SDN Pucang IV Sidoarjo, located at Jl. A. Yani No. 6A, Sidokumpul, Sidoarjo District, Sidoarjo Regency, East Java, precisely in the even semester of the 2025/2026 Academic Year. The population covered by the study reached 48 fifth grade students, spread across two study groups, namely VA and VB, each consisting of 24 students. Sampling was conducted using purposive sampling, a method of determining samples based on specific criteria or considerations (Sugiyono, 2023). These considerations stemmed from the results of an initial test conducted by the class teacher, which indicated that the majority of class VB students still scored below the Minimum Completion Criteria (KKM) for multiplication.

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Based on these findings, class VB, consisting of 24 students, consisting of 14 male students and 10 female students, was selected as the subject group that would receive treatment in this study. Meanwhile, class VA, with the same number of students, functioned as a class for instrument trials, to obtain an overview of the instrument's validity and reliability before being applied to the experimental class.

Instrument

The research instrument was a descriptive test developed based on four indicators of critical thinking skills: interpretation, analysis, evaluation, and inference (Indartiningsih et al., 2025). This descriptive test format was chosen based on the consideration that this type of test is considered more capable of comprehensively describing students' thinking processes, from understanding problems, analyzing information, evaluating answers, and drawing conclusions compared to objective tests (Faradisa et al., 2022). In the initial stage, the instrument consisted of 20 questions and was piloted in class VA. The pilot test results showed that all questions were valid. However, only 10 questions were ultimately used as the finalt instrument in the pretest and posttest in the experimental class. This decision was made due to time constraints, as completing 20 questions required up to 85 minutes, while the available time allocation was only 70 minutes. The pretest and posttest questions were structured based on identical indicators but using different numbers and contexts to minimize the possibility of memory effects in students. A detailed outline of the instrument is presented in Table 2.

Table 2. Critical Thinking Ability Test Instrument Grid

Question No.	Critical Thinking Indicators	Cognitive Domain	Question Context
1-4, 7, 8	Interpretation& Analysis	C3 (Implementing)	Determine the number of groups/rows/trays/boxes/cartons/racks based on the number of objects and contents of each group (open multiplication)
5, 6	Analysis	C4 (Analyze)	Find several possible numbers of containers and the number of objects in each container for a given total quantity.
9, 10	Evaluation& Inference	C5 (Evaluate)	Assessing the truth of an opinion regarding the results of multiplication

The questions were arranged in the form of open multiplication, namely questions that provide opportunities for students to find more than one possible answer or solution strategy (Nuryani, 2026). The validity test used Pearson Bivariate correlation with the help of IBM SPSS Statistics (valid criteria: calculated r > r table 0.455 at a significance level of 5%), and the reliability test used Cronbach's Alpha (reliable criteria: ≥ 0.60).

Procedures

The research procedure began with the development and validation of learning instruments and devices (RPM, teaching materials, LKPD, multiplication domino cards) by experts in two stages. The first validation resulted in input for improving the grammar of the test items and adjusting the pretest-posttest scores; the second validation declared all instruments and devices suitable for use. The instruments were then piloted in class VA, and after being declared valid and reliable, class VB was given a pretest using 10 selected test items.

The treatment was given in two meetings using multiplication domino cards, namely rectangular cards with one side containing multiplication problems and the other side containing answers, arranged like a domino game with an open multiplication concept. In the first meeting, students were divided into five groups, practiced solving multiplication problems using concrete objects, then arranged the domino cards sequentially according to the Student Worksheet (LKPD) and presented the results in front of the class. In the second meeting, students were divided into three larger groups, arranged the domino cards in groups with explicit direction through the stages of interpretation (identifying problem information), analysis (connecting information with the concept of multiplication), evaluation (checking calculation results through repeated addition), and inference (drawing conclusions), before completing the LKPD and presentation. After the treatment was completed, the VB class was given a posttest with the same indicators but different numbers and question contexts. Data were collected through tests (pretest-posttest scores) and documentation (recordings of learning activities during the study).

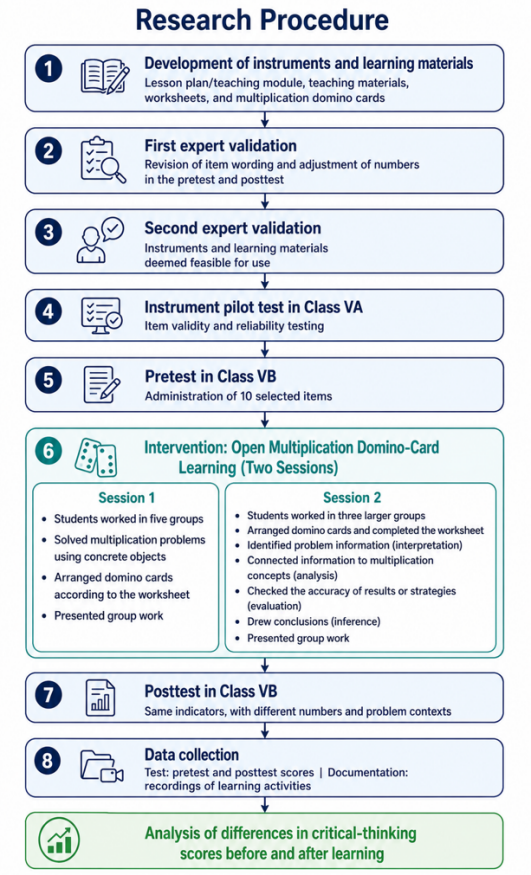

Figure 1. Research Procedure

Analysis

Data processing in this study utilized the IBM SPSS Statistics application through a series of the following stages. In the first stage, validity testing was carried out using the Pearson Bivariate correlation technique, where an item is declared valid if the Sig. value is below the threshold of 0.05, or if the calculated r value exceeds the table r value. Next, the measurement of instrument reliability was carried out through the calculation of the iCronbach's Alpha coefficient (Cronbach, 1951); an instrument is categorized as reliable if the coefficient value obtained reaches at least 0.60. Next, a normality test was applied using the Shapiro-Wilk

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technique (Shapiro & Wilk, 1965), considering the sample size was less than 50 respondents (Sugiyono, 2023). This test was not applied to each pretest and posttest score separately, but rather to the difference between the two, as a basis for determining the appropriate type of paired hypothesis test to use. Data distribution was considered normal if the resulting Sig. value was above 0.05. The fourth stage concerns hypothesis testing: the Paired Samples t-Test is applied if the data is proven to be normally distributed, while the Wilcoxon Signed Rank Test is used otherwise. H0 is rejected when the Sig. (2i-tailed) value obtained is less than 0.05. In the final stage, the effect size is also calculated using the Cohen's d formula for paired samples (Cohen, 1988), which is the average difference divided by the standard deviation of the difference, to measure the practical impact of the differences found. The overall results of this series of analyses will be presented in more detail in the Research Results section.

Results

The analysis was conducted on 24 VB class students who had complete pretest and posttest data. The results of the study are presented in four sections: instrument quality, descriptive statistics of mathematical critical thinking ability scores, normality assumption tests, and paired score difference tests and effect sizes. Because the study used a one-group pretest–posttest design without a comparison group, all findings are interpreted as changes in scores in the same group before and after participating in learning using multiplication domino cards.conceptualopen multiplication. These findings are not used to definitively establish a cause-and-effect relationship.

Validation of Learning Instruments and Tools

The mathematical critical thinking ability test instrument and learning tool were validated by experts in two stages. The first stage of validation provided input to improve the clarity of the language of several questions, align indicators between the pretest and posttest formats, adjust the numbers and context of the questions, andperfectLearning tools. The revised tools included lesson plans/teaching modules, teaching materials, student worksheets (LKPD), and multiplication domino cards. After all feedback was followed up, the second stage of validation determined that the test instruments and learning tools were suitable for use in the research.

Validity and Reliability of Instruments

The instrument was tested on 24 class VA students using 20 open-ended multiplication-based essay questions. The empirical validity of the items was analyzed using Pearson correlation between individual item scores and the total score. The analysis showed that all items had item-total coefficients that exceeded the critical value.Whichused in the study, namely .

Table 3. Summary of empirical validity results of the trial instrument

Component	Results
Number of trial participants	24
Number of items tested	20
Item–total coefficient range	0.478–0.871
Critical values used	0.455
Items meet empirical validity criteria	20 of 20
Items used in the final test	10

Empirical validity testing identified 20 valid items, from which 10 were selected for use in the final pretest and posttest. The selection was based on the representation of critical thinking indicators, alignment with the open multiplication material, variation in problem contexts, and the feasibility of the allotted testing time. The pilot test showed that completing all 20 items required approximately 85 minutes, whereas the testing time available in the actual study was limited to 70 minutes. The internal consistency of the pilot instrument was assessed using Cronbach's alpha. The analysis yielded a coefficient of 0.952 for the 20 items, indicating very high internal consistency.

Table 4. Results of the reliability of the trial instrument

Component	Mark
Cronbach's alpha	0.952
Cronbach's alpha based on standardized items	0.957
Number of grains	20
Interpretation	Internal consistency is very high

The reliability values in Table 4 were calculated for 20 items of the trial instrument. BecauseinstrumentThe final items used in the pretest and posttest consist of 10 items, the reliability of the final 10 items needs to be calculated and reported separately if data is available.

Descriptive Statistics of Pretest and Posttest Scores

The mathematical critical thinking ability score was obtained through a pretest before learning and a posttest after students attended two learning meetings using multiplication domino cards with an open multiplication concept.SecondThe test forms measure the same indicators, namely interpretation, analysis, evaluation, and inference, but use different numbers and problem contexts. The average score of mathematical critical thinking ability increased from 59.63 in the pretest to 81.88 in theposttestThus, the average score change was 22.25 points. Pretest scores ranged from 37 to 76, while posttest scores ranged from 51 to 100. All students achieved higher posttest scores than their pretest scores, with individual score changes ranging from 7 to 31 points.

Table 5. Descriptive statistics of mathematical critical thinking ability scores

Statistics	Pretest	Posttest	Difference in scores (Posttest − Pretest)
Number of students	24	24	24
Average	59.63	81.88	22.25
Minimum score	37	51	7
Maximum score	76	100	31

Normality Test of Difference Scores

In paired pretest–posttest analysis, the normality assumption is checked against the distribution of each student's difference scores, i.e., posttest minus pretest. The Shapiro–Wilk normality test is performed on these variables.ResultsThe Shapiro–Wilk test shows that there is no statistical evidence that the distribution of difference scores deviates from normality $W = 0{,}943, p = 0{,}193$. Since the significance value is greater than 0.05, the assumption of normality for the paired samples t-test analysis is met.

Table 6. Results of the Shapiro–Wilk normality test on the difference scores

Variables	n	W	p	Decision
Posttest − pretest	24	0.943	0.193	There is no evidence of deviation from normality.

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Based on these results, the analysis of the differences in pretest and posttest scores was continued using paired samples t-test.

Paired Score Difference Test

The paired-samples *t*-test showed that the posttest scores for students' mathematical critical thinking skills were significantly higher than the pretest scores. In the statistical analysis, the difference was calculated as pretest minus posttest. Therefore, the negative mean difference indicates that students' scores after the intervention were higher than their scores before the intervention. The mean pretest-posttest difference was −21.750, with a standard deviation of 5.041 and a standard error of 1.029. The analysis yielded $t(23) = -21.137$, $p < 0.001$, with a 95% confidence interval of [−23.879, −19.621]. When the difference is expressed in the posttest-pretest direction, the mean increase was 21.750 points, with a 95% confidence interval of [19.621, 23.879].

Table 7. Results of paired sample t-test scores for mathematical critical thinking ability

Comparison	Average difference	SD difference	SE	95% CI	t	df	p
Pretest – posttest	−21,750	5,041	1,029	[−23,879; −19,621]	−21,137	23	<0.001

The difference is calculated using the pretest - posttest formula. A negative value indicates that the average posttest score is higher than the average pretest score. These results provide statistical evidence to reject the null hypothesis that the mean pretest and posttest scores are the same. Thus, in the group of students studied, the mathematical critical thinking ability scores after participating in thelearningusing multiplication domino cards with an open multiplication concept was significantly higher than before learning. Therefore, there is a significant influence of multiplication domino cards on the critical thinking skills of class VB students at SDN Pucang IV Sidoarjo.

Effect Size

The magnitude of the change in scores was calculated using Cohen's α for paired data.d_zSizeThe effect is calculated by dividing the mean change in scores by the standard deviation of the difference scores:

$$d_z = \frac{\bar{D}}{SD_D}$$

Based on the average change in score of 21.750 and the standard deviation of the difference of 5.041,obtainedCohen's value of 4.32.d_z

$$d_z = \frac{21{,}750}{5{,}041} = 4{,}32$$

Table 8. Effect size of changes in mathematical critical thinking ability scores

Component	Mark
Mean change in score (Posttest − Pretest)	21,750
Standard deviation of score difference	5,041
Cohen'sd_z	4.32
Descriptive interpretation	Huge changes

The value $d_z = 4{,}32$ indicates a very large change in standardized scores within the study group. However, interpretation of the effect size requires considering the study design, which involved only one group without a comparison group. Therefore, the value reflects the magnitude of the change score before and after learning in the context of the class studied, not an estimate of the pure causal effect of the multiplication domino card media.

Summary of Findings

Overall, all 20 items in the pilot test instrument met the empirical validity criteria and the pilot test instrument showed very high internal consistency. In the research group, the average mathematical critical thinking ability score increased from 59.63 in the pretest to 81.88 in the posttest. The results of the paired samples t-test showed that the difference in scores was significant, $t(23) = -21{,}137,\ p < 0{,}001$ with an average change of 21.750 points in the posttest–pretest direction. The paired effect size indicated a very large change in scores, . These findings indicate a substantial change in mathematical critical thinking ability scores in the group of students studied after the learning, with considering the limitations of a single-group pre-experimental design.

Discussion

This study shows that students' mathematical critical thinking ability scores in the posttest were higher than their pretest scores after participating in learning using multiplication domino cards with an open multiplication concept. The average score increased from 59.63 in the pretest to 81.88 in the posttest, with an average change of 22.25 points. The results of the paired samples t-test showed that the difference was statistically significant, and the paired effect size indicated a very large change in scores (dz = 4.32). These findings indicate a substantial change in critical thinking ability scores in the group of students studied after participating in the learning series. However, because the study used a one-group pretest–posttest design without a comparison group, these results cannot be interpreted as evidence that all score changes were exclusively caused by the multiplication domino cards.

One possible explanation for these score changes is the nature of the mathematical activity constructed through open-ended multiplication dominoes. In this study, dominoes were used not only as a medium for matching multiplication expressions with a single numerical answer, but also as a means of organizing tasks that allowed students to identify important information, relate the number of groups to the contents of each group, compare possible strategies, check the accuracy of answers, and draw conclusions. In other words, the pedagogical value of dominoes in this study lay not primarily in the game itself, but in the mathematical demands and interactions generated during task completion. Learning media can function as a means of conveying messages and helping activate student engagement in learning (Briggs, in Ekayani, 2017; Fadilah et al., 2023; Karo-Karo & Rohani, 2018). However, in the context of this study, this engagement became relevant because it was directed at mathematical reasoning and justification activities, rather than simply participating in the game.

Open-ended multiplication tasks allow students to find more than one pair of factors, representations, or strategies that still satisfy the given mathematical conditions. Unlike routine multiplication exercises, which generally direct students to a single procedure and a single predetermined answer, open-ended tasks provide space for comparing solutions and explaining why a solution is acceptable. This conceptually facilitates the interpretation, analysis, evaluation, and inference processes used in this study. In the interpretation stage, students need to identify quantitative information and the demands of the problem. In the analysis stage, students connect this information with the relationship between factors and products. In the

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evaluation stage, students check the accuracy of their answers through repeated addition, the use of concrete objects, or comparisons with other strategies. In the inference stage, students draw conclusions or determine other possible appropriate multiplication pairs. Thus, the learning activities are designed to provide opportunities to use critical thinking processes as outlined in Facione's framework (in Indartiningsih et al., 2025), although this study cannot conclude that all indicators experienced the same improvement without analyzing scores per indicator.

This interpretation aligns with the view that mathematics problems that elicit diverse strategies and require justification can support the development of higher-order thinking skills (Fauzi & Abidin, 2019; Febrianti et al., 2021). The concept of open-ended multiplication in this study also aligns with the idea that multiplication learning can go beyond memorizing multiplication facts and provide students with space to explore multiplicative relations (Nuryani, 2026). Therefore, the observed improvement in scores can be understood as a pattern consistent with an instructional design that provides students with opportunities to explain, compare, and verify their mathematical ideas.

The findings of this study are consistent with those of Rofiqoh et al. (2025), who reported an increase in critical thinking skills in elementary school students after learning using multiplication domino media. This similarity suggests that domino activities have the potential to be used as a learning context that actively engages students in multiplication material. However, this study differs in the nature of the tasks used. Rofiqoh et al. (2025) used domino cards that were primarily oriented towards matching multiplication problems with a single result, whereas this study used domino cards with an open multiplication concept that allows students to consider several possible answers or strategies. This difference is important because the openness of the task has the potential to broaden the learning focus from the accuracy of results to reasoning, strategy evaluation, and answer justification. Thus, the contribution of this study lies not in the use of domino cards alone, but in redesigning domino cards as a means of open multiplication activities.

These findings are also consistent with studies reporting that domino cards can support elementary school mathematics achievement (Angraeni, 2024; Hamidah & Susanti, 2025) and research on other interactive media for multiplication, such as Powtoon (Aliyah & Purwanto, 2022) and the make-a-match model (Putri & Pranata, 2022). However, these studies need to be compared carefully due to potential differences in grade level, student characteristics, learning outcome constructs, task format, treatment intensity, instruments, and research design. Therefore, this study is not intended to suggest that open-ended multiplication domino cards are more effective than other media. Rather, these findings suggest that game media can have stronger pedagogical value when designed to encourage students to generate, compare, check, and justify mathematical solutions.

More broadly, the nature of the activities in this study aligns conceptually with the PISA 2022 orientation toward mathematical reasoning. The PISA 2022 framework places mathematical reasoning and the process of formulating situations mathematically, using concepts and procedures, and interpreting, applying, and evaluating mathematical results as essential aspects of mathematical literacy. The open-ended multiplication domino activity, which asks students to interpret information, use multiplication relations, and check the accuracy of results, can be seen as an early experience relevant to this orientation. However, this study did not use the PISA instrument, did not comprehensively measure mathematical literacy, and was conducted in only one elementary school class. Therefore, the findings cannot be used to infer the impact on PISA achievement or describe the abilities of Indonesian students

in general. PISA itself emphasizes the ability to use mathematical knowledge in non-routine situations, not simply the reproduction of routine procedures.

This study has several limitations that should be considered when interpreting the results. First, the use of a one-group pretest–posttest design without a comparison group limits causal interpretation. Differences in scores could be related to learning using multiplication dominoes, but could also be influenced by other events during the study period (history), natural changes in students (maturation), experience taking the pretest (testing effect), and possible changes or inconsistencies in the measurements (instrumentation). Second, the VB class was selected purposively because the majority of students had not yet achieved the Minimum Competency (KKM) in multiplication. This condition increases the possibility of regression to the mean, which is the tendency for very low scores in the initial measurement to move closer to the mean in subsequent measurements. Third, the number of students was limited to 24 students from one class and one school, so generalizing the results to a wider population should be done with caution. Fourth, the pretest and posttest formats had the same indicators but different numbers and question contexts. This strategy can reduce retention effects, but the equivalence of the two test formats needs to be supported by empirical evidence. Fifth, although the study documented learning activities, process data have not been systematically analyzed to show how changes in students' strategies and justifications occurred during the domino activity. Future research could strengthen the evidence through quasi-experimental designs involving comparison groups and, where possible, randomization at the classroom level. Future research should also involve a more diverse sample, measure the equivalence of the pretest and posttest forms, calculate reliability for the final 10-item instrument, and report changes in scores for each critical thinking indicator. Furthermore, collecting process data—such as recordings of group discussions, written work, short interviews, or analysis of students' strategies—could better illuminate the mechanisms of learning. With such evidence, future studies could clarify not only whether scores change, but also how and under what conditions open-ended multiplication dominoes support mathematical critical thinking processes.

Conclusion

This study found that fifth-grade students at SDN Pucang IV Sidoarjo achieved higher posttest scores in mathematical critical thinking than pretest scores after participating in learning activities using multiplication domino cards featuring open-ended multiplication tasks. The increase was statistically significant and was accompanied by a very large standardized change within the group studied. These findings suggest that open-ended multiplication domino cards have the potential to provide students with opportunities to engage in critical thinking while solving multiplication problems. The contribution of this study lies in the design of domino cards not merely as a medium for matching multiplication expressions with a single correct answer, but as an open-ended learning activity that allows students to explore multiple possible solutions, compare strategies, verify the accuracy of their answers, and justify their mathematical reasoning. For elementary school teachers, these cards may serve as an alternative interactive learning activity for multiplication, particularly when accompanied by guiding questions that encourage students to interpret information, analyze multiplication relationships, evaluate strategies, and draw conclusions. However, because this study employed a one-group pretest-posttest design without a comparison group, the findings demonstrate changes within a single group and should not be interpreted as causal evidence that the observed improvement resulted solely from the use of open-ended multiplication domino cards. Future studies should include a comparison group, involve more diverse samples, and examine changes across

individual critical thinking indicators to provide stronger evidence regarding the learning conditions and mechanisms associated with these improvements.

Conflict of Interest

The authors declare that there are no conflicts of interest.

Auhor Contributions

I.F. played a major role in the development of the research concept, methodology design, research implementation, data collection and analysis, presentation of research results, and preparation of the initial manuscript. W.M.L. contributed to research supervision, refinement of the methodology, validation of research results, critical review of the manuscript content, and editing. D.I. contributed to data validation, review of research results, and manuscript editing. F.R. contributed to critical review of the article substance, refinement of the manuscript content, and final validation. A.C. contributed to the final manuscript check, validation, and approval of the final version of the article. All authors have read, reviewed, and approved the final manuscript before publication. The percentage of author contributions to the overall research process and preparation of the article is I.F.: 70%, W.M.L.: 10%, D.I.: 8%, F.R.: 6% and A.C.: 6%

Data Availability Statement

The author declares that the data supporting the results of this study will be made available by the corresponding author, [I.F.], upon reasonable request.

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Authors Biography

	**Intan Firdaus** is a student of the Elementary School Teacher Education Study Program, Faculty of Teacher Training and Education, Universitas Nahdlatul Ulama Sidoarjo, East Java, Indonesia, class of 2022. ✉ firdausintan07@gmail.com
	**Wahyu Maulida Lestari** is a lecturer and researcher in the Elementary School Teacher Education Study Program, Faculty of Teacher Training and Education, Universitas Nahdlatul Ulama Sidoarjo, East Java, Indonesia ✉ wahyulestari.pgsd@unusida.ac.id
	**Duhwi Indartiningsih** is a lecturer and researcher in the Elementary School Teacher Education Study Program, Faculty of Teacher Training and Education, Universitas Nahdlatul Ulama Sidoarjo, East Java, Indonesia. ✉ duhwi.430@unusida.ac.id
	**Fakhrur Rozy** is a lecturer and researcher in the Elementary School Teacher Education Study Program, Faculty of Teacher Training and Education, Universitas Nahdlatul Ulama Sidoarjo, East Java, Indonesia ✉ fakhrurrozy.pgsd@unusida.ac.id
	**Ana Christanti** is a lecturer and researcher in the Elementary School Teacher Education Study Program, Faculty of Teacher Training and Education, Universitas Nahdlatul Ulama Sidoarjo, East Java, Indonesia ✉ anachristanti.pbi@unusida.ac.id