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Domino-based BILAN cards and fourth-grade students' multiplication learning outcomes: A quasi-experimental study

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ABSTRACT
Multiplication is a fundamental mathematical skill, yet many elementary school students experience difficulties because instruction is often teacher-centered and lacks engaging learning media. This study examined the effect of domino-based BILAN (Multiplication Number) cards on fourth-grade students' mathematics learning outcomes. A quasi-experimental method with a nonequivalent pretest–posttest control group design was employed. The participants were 34 fourth-grade students, consisting of 20 students in the experimental group and 14 students in the control group. Data were collected using a 20-item multiple-choice achievement test and analyzed using Jamovi 2.3.2. The instrument showed high internal consistency, with a Cronbach's alpha coefficient of .849. The reported independent-samples *t*-test indicated no significant difference between the groups' pretest scores (p = .469). However, a significant difference was found in the posttest scores (p < .001), with the experimental group achieving higher learning outcomes than the control group. These findings suggest that domino-based BILAN cards can support multiplication learning by providing a more engaging and interactive learning experience. Therefore, this medium may serve as an alternative instructional tool for teaching multiplication in elementary schools.

INTRODUCTION

Mathematics education at the elementary-school level provides an essential foundation for students' subsequent academic development. Among the four basic arithmetic operations, multiplication has a particularly important role because mastery of basic multiplication facts supports the learning of division, fractions, multidigit calculation, algebra, and more advanced mathematical problem-solving. Nevertheless, multiplication is not equally accessible to all learners. Elementary-school students demonstrate considerable differences in their multiplication ability, particularly in the transition from using procedural strategies—such as repeated addition and skip counting—to retrieving multiplication facts efficiently from memory (van der Ven et al., 2015). Memorizing multiplication tables can also be challenging because students must distinguish among numerous similar arithmetic facts, which may generate interference during learning and retrieval (Dotan & Zviran-Ginat, 2022).

Developing multiplication proficiency therefore requires more than asking students to memorize isolated number facts. Students need structured opportunities to understand multiplication relationships, practise repeatedly, receive feedback, and gradually develop efficient solution strategies. Systematic practice can improve students' recall of multiplication facts, but the format of that practice influences how students participate in and respond to instruction (Wong & Evans, 2007). Recent evidence also suggests that multiplication games can encourage students to move from early strategies, including direct modelling and repeated addition, toward derived-fact strategies and direct recall, although the magnitude of improvement may vary across learning conditions (Polly et al., 2025).

This instructional challenge is particularly relevant when mathematics lessons remain dominated by teacher explanations, textbooks, and routine written exercises. Preliminary observations reported in the original manuscript indicated that multiplication instruction in the participating elementary schools made limited use of supporting learning media. Students consequently had few opportunities to interact with multiplication concepts through concrete, collaborative, and game-oriented activities. The manuscript also reported that students demonstrated limited enthusiasm during lessons and experienced difficulties understanding and recalling multiplication facts. These classroom conditions indicate a need for learning media that can make abstract numerical relationships more visible and provide students with meaningful opportunities to practise.

Concrete learning materials may help address this need by connecting mathematical symbols with observable and manipulable representations. A meta-analysis of 55 studies involving 7,237 learners found that instruction incorporating concrete manipulatives produced small-to-moderate benefits compared with instruction based only on abstract mathematical symbols. The strongest advantages were identified for the retention of mathematical knowledge, although the effectiveness of manipulatives depended on how the materials were integrated into instruction (Carbonneau et al., 2013). Thus, learning media should not merely function as attractive physical objects; they should be aligned with clear mathematical objectives and accompanied by carefully designed learning activities.

Game-based learning offers another relevant instructional approach. Educational games can integrate cognitive activity, motivation, emotion, behaviour, and social interaction within a structured learning environment. From this perspective, games are educationally valuable when their rules, challenges, feedback, and interactions require students to engage directly with the intended learning content (Plass et al., 2015). In mathematics education, game-based activities can provide repeated practice in a less monotonous format, encourage active participation, and create opportunities for students to discuss answers and strategies with their peers. A meta-analysis of 24 studies found that mathematics game-based learning produced higher learning gains than conventional instruction, although the overall effect was relatively small and varied according to the learners, intervention characteristics, and research context (Tokac et al., 2019). These findings suggest that games may support mathematics achievement, but their effectiveness cannot be assumed without empirical evaluation.

Card-based games represent a practical form of game-based learning because they are inexpensive, reusable, and relatively easy to implement in classrooms with limited technological resources. Previous research has demonstrated the potential of multiplication cards as elementary-school learning media. Astriani and Khairani (2022), for example, developed the Multiple Math Card as a game-oriented medium for teaching multiplication and found it to be valid and practical based on expert appraisal and classroom trials. However, validity and practicality do not necessarily demonstrate that a learning medium improves achievement compared with regular instruction. Similarly, Polly et al. (2025) found that fourth-grade students who participated in multiplication fluency games showed greater growth than students who used pictorial flashcards, but the between-group difference was not statistically significant. Accordingly, further comparative research is required to determine the conditions under which card games contribute meaningfully to multiplication achievement.

One card-based medium that may be used for this purpose is the BILAN card, an abbreviation for Bilangan Perkalian or Multiplication Number. The medium adapts the matching mechanism of domino games to multiplication content. Instead of matching identical symbols, students connect multiplication expressions with their corresponding products. The cards are used in small groups, requiring students to identify answers, place cards according to the game rules, observe their peers' moves, and repeatedly process multiplication facts. This combination of physical manipulation, repeated retrieval, game rules, and peer interaction is expected to make multiplication practice more active than conventional textbook-based exercises. The original manuscript positions BILAN cards as a concrete and game-oriented medium intended to improve students' concentration, participation, and mastery of multiplication facts.

Although domino games and multiplication cards have previously been used in mathematics instruction, several research gaps remain. First, much of the broader game-based learning literature concerns digital games, whereas teachers in resource-limited elementary schools may require effective non-digital alternatives. Second, several card-media studies have focused primarily on product development, expert validation, or practicality rather than comparative learning outcomes. Third, recent findings concerning multiplication games have not been entirely consistent, indicating that their effectiveness may depend on the design of the game, duration of implementation, instructional guidance, and characteristics of the participating students. Finally, limited evidence is available regarding the use of a domino-based multiplication card medium among fourth-grade students in the Indonesian elementary-school context.

Therefore, this study examined the effect of domino-based BILAN cards on the mathematics learning outcomes of fourth-grade elementary-school students. Specifically, it compared the multiplication achievement of students who learned using BILAN cards with that of students who received conventional instruction. It was hypothesized that students taught using domino-based BILAN cards would demonstrate higher post-intervention mathematics learning outcomes than students in the control group. The study is expected to provide empirical evidence regarding the use of an affordable, concrete, and collaborative learning medium for elementary multiplication instruction.

RESEARCH METHODS

Research Design

This study employed a quantitative approach using a quasi-experimental design. More specifically, a nonequivalent pretest–posttest control group design was used to examine the effect of domino-based BILAN (Bilangan Perkalian, or Multiplication Number) cards on fourth-grade students' mathematics learning outcomes. This design was selected because the participants were drawn from existing classes and could not be randomly assigned to the experimental and control conditions.

Both groups completed a pretest before the intervention and a posttest after the intervention. The experimental group learned multiplication using domino-based BILAN cards, whereas the control group received conventional mathematics instruction without the BILAN card medium. The pretest was administered to identify students' initial multiplication achievement, while the posttest was used to evaluate their achievement after the instructional period.

The BILAN cards adapted the matching mechanism of a domino game to multiplication content. During the learning activities, students worked in small groups and matched multiplication expressions with their corresponding products. The activities were intended to provide repeated practice, encourage active participation, and facilitate peer interaction while students learned basic multiplication facts. To ensure replicability, the final manuscript should also specify the number of instructional sessions, the duration of each session, the teacher responsible for each group, and the detailed instructional procedures implemented in both groups.

Participants

The population of the study consisted of fourth-grade students from public elementary schools in Cluster 5, Ngunut District. The participants were selected from two intact fourth-grade classes because random assignment of individual students was not feasible within the participating schools. A total of 34 students participated in the study. The experimental group consisted of 20 fourth-grade students from SD Negeri Samir, while the control group consisted of 14 fourth-grade students from another public elementary school in the same district. The experimental class received instruction using domino-based BILAN cards, whereas the control class received conventional instruction.

Because the participants came from intact classes at different schools, the assignment to the experimental and control conditions was nonrandom. Consequently, potential differences in school environment, teacher characteristics, classroom practices, and student backgrounds could not be completely controlled. This limitation should be considered when interpreting the findings. Information concerning the students' age, gender distribution, previous mathematics achievement, inclusion criteria, and attendance during the intervention was not provided in the original manuscript and should be added when available.

Collecting Data

Data were collected through classroom observation, a mathematics achievement test, and documentation. Preliminary classroom observations were conducted to identify the instructional conditions and difficulties experienced by students when learning multiplication. The observations indicated that mathematics instruction was predominantly teacher-centered and relied mainly on textbooks, with limited use of concrete or game-based learning media.

The primary data-collection instrument was a mathematics achievement test consisting of 20 multiple-choice questions covering fourth-grade multiplication content. The same test framework was used for the pretest and posttest. The pretest was administered before the intervention to measure students' initial achievement, whereas the posttest was administered after the intervention to assess their achievement following the respective instructional conditions.

The manuscript reports that the test instrument was evaluated using reliability and item analyses. The internal consistency coefficient was Cronbach's alpha = .849, indicating satisfactory reliability. The item-rest correlations ranged from .283 to .645. However, the original manuscript does not clearly explain whether the students involved in the instrument trial were different from those participating in the main study. This information should be clarified in the final version.

The original manuscript also reported exploratory factor analysis. Nevertheless, because the reported instrument-testing sample was relatively small for factor analysis, evidence of instrument quality should primarily be supported by expert-based content validation, item-rest or point-biserial correlations, item difficulty, item discrimination, and reliability analysis. The number and qualifications of the validators, the validation procedure, and the criteria used to retain or remove items should be reported when these data are available. Documentation was used to support the research process, including student participation records, instructional activities, test administration, and other relevant classroom information.

Data Analysis

The data were analyzed using Jamovi version 2.3.2. The internal consistency of the mathematics achievement test was examined using Cronbach's alpha, while item quality was evaluated using item-rest correlation coefficients. The normality of the pretest and posttest scores was assessed using the Shapiro–Wilk test and Q–Q plots. Levene's test was subsequently conducted to examine the homogeneity of variance between the experimental and control groups.

Independent-samples t-tests were used to compare the mathematics achievement scores of the experimental and control groups. The first analysis compared the groups' pretest scores to determine whether there was evidence of a difference in their initial achievement. The second analysis compared the groups' posttest scores after the experimental group had received instruction using domino-based BILAN cards. Statistical significance was determined at an alpha level of .05. A result with $p < .05$ was interpreted as statistically significant, whereas a result with $p \geq .05$ was interpreted as insufficient evidence to reject the null hypothesis.

Because the original dataset and complete descriptive statistics were unavailable, the analysis was limited to the inferential statistics reported in the available research document. Therefore, group means, standard deviations, confidence intervals, effect-size estimates, and adjusted posttest scores could not be calculated.

RESULTS

Instrument Quality

The mathematics achievement test consisted of 20 multiple-choice items and was piloted with 34 fourth-grade students. Internal consistency analysis produced a Cronbach's alpha coefficient of .849, indicating satisfactory reliability. The item-rest correlation coefficients ranged from .283 to .645. All coefficients were positive, although Items 4 and 5 showed relatively low correlations of .299 and .283, respectively. These items should therefore be reviewed in relation to their content, level of difficulty, and discrimination indices before the instrument is used in future studies.

Table 1. Reliability of the Mathematics Achievement Test

Number of items	*Cronbach's α*
20	.849

An exploratory factor analysis was also conducted to examine the structure of the achievement test. Bartlett's test of sphericity was statistically significant, $\chi^2(190) = 419$, $p < .001$, indicating that the item correlation matrix was not an identity matrix. The first factor had an eigenvalue of 4.555, whereas the second factor had an eigenvalue of .970. The remaining factors had lower eigenvalues. Based on the reported scree plot and eigenvalues, the first factor appeared to be more prominent than the other factors.

Table 2. Bartlett's Test of Sphericity

χ^2	*df*	*p*
419	190	< .001

Only the five largest eigenvalues are presented here for conciseness. Because the instrument trial involved only 34 students, the exploratory factor analysis should be interpreted cautiously. The final manuscript should place greater emphasis on content validity, item discrimination, item difficulty, and reliability evidence.

Table 3. Initial Eigenvalues

Factor	*Eigenvalue*
1	4.555
2	.970
3	.691
4	.603
5	.494

Assumption Testing

Before comparing the experimental and control groups, normality and homogeneity-of-variance tests were conducted. The Shapiro–Wilk test indicated that the pretest scores did not significantly deviate from normality, W = .964, p = .289. The posttest scores also showed no statistically significant deviation from normality, W = .968, p = .375. The Q–Q plots presented in the original manuscript similarly showed that the observed values were located relatively close to the reference line.

Table 4. Shapiro–Wilk Normality Test

Measurement	*W*	*p*
Pretest	.964	.289
Posttest	.968	.375

Levene's test indicated that the variance of the pretest scores was not significantly different between the groups, F(1, 34) = 1.510, p = .228. The same result was found for the posttest scores, F(1, 34) = .596, p = .445. Therefore, the homogeneity-of-variance assumption was considered satisfied for the reported independent-samples comparisons.

Table 5. Levene's Test for Homogeneity of Variance

Measurement	***F***	**df1**	**df2**	***p***
Pretest	1.510	1	34	.228
Posttest	.596	1	34	.445

Comparison of Learning Outcomes

An independent-samples t-test was conducted to compare the mathematics learning outcomes of the experimental and control groups. The pretest results showed no statistically significant difference between the two groups, t(34) = −0.733, p = .469. Therefore, the available evidence did not indicate a significant difference in the students' initial multiplication achievement.

In contrast, the posttest results showed a statistically significant difference between the experimental and control groups, t(34) = 4.849, p < .001. As reported in the original study, students in the experimental group achieved higher posttest scores than students in the control group. This result indicates that students who learned multiplication using domino-based BILAN cards demonstrated better post-intervention learning outcomes than those who received conventional instruction.

Table 6. Independent-Samples t-Test Results

Measurement	*t*	*df*	*p*	*Interpretation*
Pretest	−0.733	34	.469	No statistically significant difference
Posttest	4.849	34	< .001	Statistically significant difference

The reported results suggest that the two groups did not differ significantly before the intervention, whereas a significant difference was observed after the intervention. However, because group means, standard deviations, confidence intervals, and effect-size estimates were not available, the magnitude of the difference could not be determined from the reported data. Consequently, the findings should be interpreted primarily in terms of statistical significance rather than the size of the intervention effect.

DISCUSSION

This study examined the use of domino-based BILAN cards in teaching multiplication to fourth-grade elementary-school students. The reported results showed no statistically significant difference between the experimental and control groups' pretest scores. In contrast, a statistically significant difference was found between the groups' posttest scores, with the original report indicating that the experimental group achieved higher scores than the control group. These findings suggest that the use of domino-based BILAN cards was associated with better post-intervention mathematics learning outcomes than conventional instruction. Nevertheless, the absence of a significant pretest difference should not be interpreted as definitive evidence that the two groups were equivalent before the intervention, particularly because the participants were not randomly assigned.

A plausible explanation for the reported posttest difference is that the BILAN cards transformed multiplication practice into a structured game-based activity. During the activity, students were required to identify multiplication expressions, retrieve the corresponding products, match the cards correctly, and respond to the moves made by other group members. These processes may have encouraged students to engage cognitively with multiplication facts while also participating behaviorally and socially in the learning activity. Plass et al. (2015) explain that the educational value of game-based learning is not derived from enjoyment alone. Rather, effective games combine cognitive, motivational, affective, behavioral, and sociocultural forms of engagement with clearly defined learning content. From this perspective, the BILAN cards may have supported learning because the rules of the game required students to process multiplication facts continuously rather than merely observe the teacher's explanation.

The repeated matching of multiplication expressions and products may also have provided opportunities for retrieval practice. Instead of only reading or reciting multiplication tables, students had to retrieve answers whenever they attempted to place a card. Retrieval practice can strengthen the accessibility of information in memory, particularly when practice is distributed and learners repeatedly attempt to recall the correct response. In an authentic elementary-school setting, Ophuis-Cox et al. (2023) found that retrieval practice using flashcards produced stronger short- and longer-term improvements in multiplication-fact fluency than restudying multiplication facts through oral repetition. Although the present study did not directly measure retrieval fluency, the matching mechanism used in BILAN cards may have encouraged a similar process of repeated retrieval. This explanation should, however, be regarded as an interpretation rather than a directly tested mechanism.

Another possible explanation concerns the concrete and manipulable characteristics of the cards. Multiplication expressions are abstract symbolic representations, particularly for elementary-school students who have not yet developed fluent numerical relationships. The use of physical cards allows students to manipulate, compare, arrange, and connect multiplication expressions with their products. Carbonneau et al. (2013), in a meta-analysis of 55 studies involving 7,237 learners, found small-to-moderate advantages for mathematics instruction incorporating concrete manipulatives compared with instruction based only on abstract mathematical symbols. The benefits were particularly evident for knowledge retention, although the effects varied according to instructional and methodological characteristics. Consequently, the presence of physical cards alone cannot guarantee learning. Their effectiveness depends on whether the teacher explicitly connects the card activity with the underlying multiplication concepts.

The findings are generally consistent with previous research indicating that card- and game-based media can support mathematics instruction. Astriani and Khairani (2022) developed the Multiple Math Card as a game-oriented medium for teaching multiplication in elementary schools and reported that the product met validity and practicality criteria. Similarly, Marian and Yansyah (2021) reported that the use of domino games was associated with mathematics learning outcomes. These studies support the practical potential of card-based media, particularly because such media are inexpensive, reusable, and suitable for classrooms with limited access to digital technology. The present study extends this line of work by comparing students who used a domino-based multiplication medium with students who received conventional instruction.

Nevertheless, the broader literature indicates that game-based learning does not invariably produce large or statistically significant improvements. Tokac et al. (2019) synthesized 24 studies comparing mathematics video games with conventional instruction and identified a small overall advantage for game-based learning, accompanied by considerable variation in the magnitude and direction of the effects. Although their review focused primarily on digital games, its findings emphasize that learning outcomes depend on the game design, intervention duration, learner characteristics, assessment instruments, and instructional context. Therefore, the significant posttest difference reported in the present study should not be interpreted as evidence that every educational game will automatically improve mathematics achievement.

The present findings should also be considered alongside more specific evidence concerning multiplication games. Polly et al. (2025) compared fourth-grade students who participated in multiplication-fluency games with students who used pictorial flashcards during a six-week intervention. Students in the game condition demonstrated greater growth, but the difference between the two groups was not statistically significant. Interviews nevertheless indicated changes in students' multiplication strategies, with students moving away from direct modeling, repeated addition, and skip counting toward derived-fact strategies and direct recall. These findings suggest that multiplication games may influence not only test scores but also how students approach multiplication problems. The present study did not examine students' solution strategies, so it cannot determine whether BILAN cards produced similar strategic changes. Future studies should assess both achievement and the development of multiplication strategies.

From a pedagogical perspective, BILAN cards may provide elementary-school teachers with an accessible alternative to routine multiplication exercises. The cards can be used in small groups to create repeated practice while maintaining students' active involvement. However, their use should be accompanied by clear instructional guidance. Teachers should ensure that all students participate rather than allowing only faster or higher-achieving students to dominate the game. They should also pause the activity to discuss multiplication patterns, explain incorrect responses, and connect the matched cards with repeated addition, arrays, equal groups, and other conceptual representations. In this way, the game functions as a component of mathematics instruction rather than merely as entertainment.

Several limitations must be considered when interpreting the findings. First, the study used intact classes from different schools, and the students were not randomly assigned to the experimental and control groups. As a result, the instructional treatment was confounded with possible differences in teachers, school environments, classroom routines, facilities, and student backgrounds. The reported posttest difference therefore cannot be attributed exclusively to the BILAN cards. Second, the total sample was relatively small, consisting of 34 students, which limits the generalizability and statistical stability of the findings. Third, the analysis compared the pretest and posttest scores using separate independent-samples t-tests. This approach does not control statistically for individual differences in initial achievement as effectively as ANCOVA or a mixed-design analysis.

A further limitation concerns the absence of group-level descriptive statistics, confidence intervals, and effect-size estimates in the available report. Although statistical significance was reported, the magnitude and educational importance of the difference could not be evaluated. Moreover, the available data did not permit an analysis of whether students maintained their multiplication achievement after the intervention. The study also did not measure student engagement, motivation, multiplication strategies, or implementation fidelity. It therefore remains unclear which specific aspects of the BILAN-card activity contributed most strongly to the reported outcome.

Future research should involve larger samples from multiple schools and, where feasible, randomly assign classes to instructional conditions. Researchers should report the means, standard deviations, confidence intervals, and effect sizes for each group. ANCOVA may be used to compare posttest scores while controlling for initial achievement, whereas mixed-effects models may be appropriate when students are nested within classes or schools. Future studies should also document the number and duration of instructional sessions, the teachers involved, adherence to the intervention procedures, and the instructional activities used in the control group. Delayed posttests would help determine whether the learning gains are retained. In addition, observations and interviews could examine whether BILAN cards influence students' participation, motivation, peer interaction, and multiplication strategies.

The reported results provide preliminary support for domino-based BILAN cards as a concrete and interactive medium for multiplication instruction. The cards appear to offer opportunities for repeated retrieval, physical manipulation, and peer-supported learning. However, because of the quasi-experimental design, small sample, limited statistical reporting, and possible school-level differences, the findings should be regarded as initial evidence rather than definitive proof of effectiveness.

CONCLUSION

This study examined the use of domino-based BILAN cards in teaching multiplication to fourth-grade elementary-school students. The reported findings showed no statistically significant difference between the experimental and control groups' pretest scores, whereas a statistically significant difference was found in the posttest scores. Based on the original report, students who learned using domino-based BILAN cards achieved higher post-intervention mathematics learning outcomes than those who received conventional instruction.

The findings indicate that BILAN cards may serve as an engaging and practical instructional medium for multiplication learning. By combining repeated practice, physical card manipulation, game rules, and peer interaction, the activity may encourage students to participate more actively in mathematics lessons. Therefore, BILAN cards can be considered as an alternative supplementary medium for elementary-school teachers when teaching basic multiplication facts.

However, the findings should be interpreted cautiously. The participants were drawn from intact classes at different schools, the sample size was relatively small, and the students were not randomly assigned to the experimental and control groups. In addition, detailed descriptive statistics, confidence intervals, and effect-size estimates were unavailable, and the analysis relied on separate independent-samples t-tests. Consequently, the results provide preliminary rather than conclusive evidence of the effectiveness of domino-based BILAN cards.

Future studies should involve larger and more diverse samples, provide complete descriptive and inferential statistics, control for students' initial achievement, and examine the retention of learning outcomes. Further research should also investigate whether BILAN cards influence students' motivation, participation, peer interaction, and multiplication strategies.

Declaration on the Use of AI Statement

During the preparation of this work, the authors used AI tools to improve the readability and language of the manuscript. After using this tool, the authors carefully reviewed and edited the content as needed and take full responsibility for the content of the published article.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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