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Research Article

DEVELOPMENT OF MATHEMATICS LEARNING USING BATAK CULTURE-BASED MEDIA IN INDONESIA

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Abstract
This study aims to develop Batak culture-based domino card learning media to enhance students' interest and academic achievement in three challenging mathematics topics: trigonometry, integer operations, and logarithms. The research explores how local cultural values, specifically the Batak kinship philosophy *Dalihan Na Tolu,* can be meaningfully integrated into mathematics instruction. Employing a design-based research (DBR) approach, the study was conducted in seven schools across North Sumatra Province, Indonesia. The development process encompassed media design, expert validation, classroom implementation, and iterative refinement. Instruments utilized included teacher interviews, classroom observations, student questionnaires, and achievement tests. The findings indicate that integrating *Dalihan Na Tolu* values into game- based learning media provides culturally resonant analogies that enhance students' understanding of abstract mathematical concepts. In trigonometry, visual and cultural representations helped students distinguish among triangle elements and apply ratio concepts in problem-solving. In the context of integer operations, the domino gameplay facilitated students' comprehension of signed numbers through contextual scenarios such as altitude and temperature changes. For logarithms, visual simulations and matching exercises supported students in grasping the inverse relationship between exponents and logarithmic expressions. The application of culturally contextualized game-based media not only improved students' comprehension across all three mathematical topics but also significantly increased their engagement and interest in learning. These findings suggest that incorporating local cultural values into instructional tools can offer an innovative and effective model for advancing mathematics education, particularly in culturally diverse contexts.

Keywords: Batak Indigenous Culture, Cultural Integration of Dalihan Na Tolu, Domino Card Media, Learning Mathematics, Visualization of Teaching Materials.

INTRODUCTION

Education plays a crucial role in shaping an individual's identity (Dart et al., 2022). Through education, individuals are not only equipped with knowledge but are also nurtured to become people of faith, integrity, creativity, and resilience in facing life's challenges (Meihami, 2022). Learning, as a central aspect of education, is a dynamic interaction between educators and students, aiming to bring about both behavioral and intellectual growth. Vodă & Florea (2019) emphasize that learning is not just about behavioral change, but also about the development of individual character and personality.

However, mathematics remains one of the least favored subjects among students. Many perceive it as abstract and difficult due to its symbolic nature and lack of connection to real-life situations (Niss & Højgaard, 2019; Li et al., 2021; Ariyani et al., 2025; Beltran, 2025). Trigonometry, for instance, is often taught in a theoretical and abstract manner, which can hinder students' comprehension of its concepts. A contextual approach is therefore needed to bridge the gap between abstract mathematical ideas and students' real- world experiences (Hornburg et al., 2021). Similarly, integer operations are frequently introduced through symbolic rules without sufficient real-life context, which can cause confusion among students, especially when dealing with negative values. A contextual and visual approach is essential to help learners internalize the meaning of positive and negative numbers in practical scenarios such as elevation, temperature changes, or financial gains and losses. Likewise, logarithms are among the most abstract topics in mathematics, often presented as purely formulaic without concrete applications. This abstraction makes it difficult for students to grasp the inverse relationship between exponents and logarithms. Introducing logarithmic concepts through real-world analogies, such as sound intensity or population growth, can significantly enhance conceptual understanding and relevance. One such approach involves integrating local culture into the learning process.

In the context of North Sumatra, Indonesia, Batak culture particularly that of the Batak Toba community offers a rich resource for contextualized learning. The Dalihan Na Tolu system, a central element of Batak social philosophy, represents a kinship structure involving three interconnected roles: hula-hula (wife giver), dongan tubu (clan peers), and anak boru (wife taker) (Firmando, 2021). This structure is symbolized by three stones arranged in an equilateral triangle used as a traditional cooking stove, where each stone supports and balances the others (Harianja & Sudrajat, 2021). This symbolic triangle is not only culturally significant but also geometrically aligned with the concept of trigonometry. Just as the three stones must support each other equally for the structure to function, the sides and angles of a triangle are interdependent in trigonometric ratios such as sine, cosine, and tangent.

The values embodied in *Dalihan Na Tolu* are mutual respect, responsibility, and balance, offer meaningful analogies for understanding various mathematical relationships. In trigonometry, for instance, the interdependence between the sides and angles of a triangle reflects the balance and harmony required among the three kinship roles of *hula-hula*, *dongan tubu*, and *boru* in Batak culture. These cultural values, which emphasize collaboration and social cohesion, align with the goals of character education and cooperative learning (Muda & Suharyanto, 2020). In integer operations, the interaction between positive and negative numbers mirrors the dynamic of opposing social roles working together to achieve equilibrium, just as Batak kinship roles must operate in harmony to preserve social stability. Similarly, in logarithmic concepts, the interconnectedness of base, exponent, and logarithm resembles the triadic nature of *Dalihan Na Tolu*, where each element has a distinct function but must relate coherently with the others to form a complete system. Despite the richness of these parallels, current mathematics materials often lack visual, contextual, and culturally relevant components to support deeper learning. By embedding mathematical operations within the framework of a culturally familiar philosophy, students not only gain clearer conceptual understanding but also strengthen their connection to local cultural values.

Through field observations and interviews conducted in several schools, the researchers found that students often struggle with understanding trigonometric ratios due to the abstract nature of the material, limited real-world connections, and a lack of engaging visualization in existing learning resources. Previous studies (Kamber & Takaci, 2017) and more recent findings also confirm these challenges. Similar difficulties were observed in learning integer operations, where students frequently misunderstand the rules of signed numbers, especially when concepts are presented symbolically without relatable context. The lack of concrete representations often results in confusion regarding directionality and value interpretation. In the case of logarithms, the abstract inverse relationship between exponents and logarithmic expressions presents an even greater challenge. Students struggle to apply these concepts

meaningfully without access to real-world analogies or visual tools that bridge the gap between theory and application. These findings suggest a critical need for domino card that integrate visualization, interactivity, and cultural relevance to support conceptual understanding across these mathematical topics.

In parallel, advances in technology and the evolving expectations of 21st-century education demand innovative teaching approaches (Szymkowiak et al., 2021; De Vries, Bliznyuk, & Pinedo, 2023; Endra & Villaflor, 2024; Cortés et al., 2025; Dzulfikar et al., 2025). In the era of Industry 4.0 and Society 5.0, teachers must continuously adapt their teaching methods to align with trends and students' learning needs (Caena & Redecker, 2019; Azevedo et al., 2023). One promising method is the use of interactive media and educational games, which have been shown to enhance engagement, motivation, and understanding in mathematics learning (Wang et al., 2021; Ziatdinov & Valles, 2023; Ikhsan et al., 2025; Nou et al., 2025). Visual and interactive representations such as simulations, diagrams, and games allow students to concretely explore abstract mathematical concepts (Moyer-Packenham et al., 2022; Xu, Kang, & Yan, 2022; Afriani & Widodo, 2025; Fernandez et al., 2025; Julianti et al., 2025).

Games like dominoes, when designed with mathematical objectives, can help students visualize, practice, and internalize concepts while also having fun (Russo, Bragg, & Russo, 2021). Studies have found that domino-based learning media can effectively support conceptual understanding and increase enthusiasm in subjects like algebra and number operations (Setiawan, Yandari, & Pamungkas, 2020; Umbara et al., 2021; HN, Madlazim, & Supardi, 2023). Despite these promising developments, this research has explored how local cultural values such as the Batak kinship system can be meaningfully embedded in trigonometry, logarithm and integer operations learning using interactive, game-based media. While traditional instruction may emphasize rules and formulas, it rarely connects these concepts to students' everyday experiences or local wisdom. Embedding cultural frameworks like *Dalihan Na Tolu* into these mathematical domains holds potential not only to improve comprehension but also to foster a deeper appreciation of students' heritage through meaningful and engaging learning experiences.

RESEARCH METHOD

This study employed a mixed-method approach that combined development research with a quasi-experimental design to evaluate the effectiveness of Batak culture-based domino learning media. The research was conducted across three different mathematical topics namely integer operations, trigonometry, and logarithm at both junior and senior high school levels. The development phase involved designing domino cards integrated with culturally relevant visual elements inspired by the Dalihan Na Tolu philosophy. The design process included expert validation from content and media specialists to ensure the appropriateness and clarity of both mathematical content and cultural representations. Feedback was used to revise and improve the media before implementation.

The implementation phase utilized a quasi-experimental design with a non-equivalent control group. Participants consisted of students from several schools in North Sumatra, divided into experimental groups (taught using the domino media) and control groups (taught using conventional methods). Pretests and posttests were administered to measure students' learning outcomes. Additionally, student response questionnaires were distributed to assess levels of motivation, engagement, and perceived effectiveness of the media. Descriptive and inferential statistical analyses were applied to compare the learning gains between groups. The research design also incorporated qualitative observations during class activities to capture students' interactions and engagement with the learning materials.

The research subjects consisted of students and mathematics teachers from several junior and senior high schools across various regions in North Sumatra, Indonesia. The selection of research subjects was carried out using a purposive sampling technique, a non-probability sampling method in which participants are deliberately chosen based on specific characteristics relevant to the research objectives (Amir, Jabeen, & Niaz, 2020). These characteristics include the school's geographical location (urban and remote), cultural background (Batak culture), and the grade level aligned with the trigonometry curriculum.

At the junior high school level, one Grade IX class was selected from each of the following schools:

- State Junior High School 21 Medan (Class IX-2)
- State Junior High School 7 Tanjung Balai (Class IX-1)
- State Junior High School 1 Sosopan (Class IX-1)

At the senior high school/vocational school level, one Grade X class was selected from each of the following schools:

- State Vocational High School 1 Medan (Class X-Par-1)
- State Vocational High School 1 Sei Rampah (Class X-TKJ 1)
- Pembangunan Private Senior High School (Class X IPA 3)
- Al Ma'shum Private Senior High School (Class X-IPA 1)

In each school, students in the selected class and their respective mathematics teachers participated in the research. The number of participants per class varied depending on class size but was sufficient to provide in-depth data through classroom observations, student questionnaires, and teacher interviews. This purposive sampling strategy ensured that the selected subjects were well-suited to provide meaningful insights into the integration of local cultural values into mathematics learning and the effectiveness of the instructional media developed for this study.

The procedures carried out in this study are summarized in Table 1.

Table 1. Research Procedure

Step	Description
Step 1	Determining research locations in seven selected schools across North Sumatra.
Step 2	Selecting research subjects using purposive sampling (one class per school).
Step 3	Developing research instruments, including interview guidelines, observation sheets, and student questionnaires.
Step 4	Conducting initial classroom observations at four nearby schools.
Step 5	Conducting teacher interviews in remote schools as substitutes for on-site observation.
Step 6	Designing instructional media, including domino card games and visual teaching materials.
Step 7	Validating the instructional media for content accuracy and cultural relevance.
Step 8	Implementing the validated media in selected classrooms.
Step 9	Collaborating between researcher and classroom teacher during the learning process.
Step 10	Conducting the learning activities over four class periods.
Step 11	Integrating Batak cultural values such as kinship and symbolism into the lesson.
Step 12	Observing classroom activities to monitor media effectiveness and student engagement.
Step 13	Interviewing teachers to gather feedback on the learning process and media used.
Step 14	Distributing questionnaires to students to assess understanding and cultural reflection.
Step 15	Classifying and thematizing the collected data.
Step 16	Interpreting data to understand learning outcomes and cultural impact.
Step 17	Writing a detailed narrative of research findings.
Step 18	Conducting data triangulation to ensure validity of the results.

This study employed multiple research instruments to obtain comprehensive and valid data on the integration of Batak cultural elements into mathematics learning. The instruments were designed to capture various aspects of the teaching and learning process, student responses, and cultural relevance. This study employed several research instruments to collect both quantitative and qualitative data. The main instruments included pretests and posttests, student questionnaires, interview guidelines, and observation sheets. The pretests and posttests were used to evaluate students' cognitive understanding of specific mathematical topics namely trigonometry, integer operations, and logarithmic expressions before and after the use of the domino card. These tests were aligned with national curriculum standards and designed to suit the students' academic level.

To capture students' attitudes and perceptions, a structured questionnaire was distributed following the intervention. This questionnaire consisted of items measured using a Likert scale, focusing on aspects such as student motivation, engagement, clarity of the content, cultural relevance, and enjoyment of the learning process using the domino media. Qualitative insights were gathered through semi-structured interview guidelines aimed at teachers. These interviews explored the effectiveness of

the domino card, classroom dynamics, student reactions, and how well the cultural elements were embedded in the learning experience. Additionally, classroom observation sheets were utilized to systematically record students' behaviors, collaboration, and interaction with the media throughout the teaching sessions.

The data collection process in this study was carried out systematically over three main phases: preparation, implementation, and evaluation. Each phase employed a combination of qualitative and quantitative techniques to ensure comprehensive and valid data acquisition. In the preparation phase, preliminary classroom observations were conducted in several schools to understand the existing teaching environment, identify instructional challenges, and assess students' prior familiarity with mathematical concepts such as trigonometry, integer operations, and logarithms. These observations provided valuable contextual information that informed the development of relevant domino card. In remote schools where direct observation was not feasible, teacher interviews were conducted to gain similar insights. During this stage, all research instruments including pretests, posttests, questionnaires, and observation sheets were also designed and validated by experts in mathematics education and cultural studies.

The implementation phase began with the administration of pretests to both the experimental and control groups to establish baseline knowledge. Subsequently, learning using domino cards was implemented in selected experimental classes during four learning sessions. During this period, researchers collaborated closely with classroom teachers and used observation sheets to monitor student engagement, participation, and interaction with the media. This phase also involved real-time documentation of how Batak cultural elements were integrated into the lessons.

Finally, in the evaluation phase, posttests were administered to evaluate students' academic improvement after the learning intervention. A structured student questionnaire was distributed to measure their responses to the media in terms of clarity, motivation, cultural connection, and enjoyment. In-depth interviews with teachers were also conducted to gather qualitative feedback on the effectiveness of the media, its cultural integration, and its impact on classroom dynamics. Through these three phases, data were collected from multiple sources using various techniques, allowing for triangulation and validation of findings across instruments and respondent groups. This rigorous data collection approach strengthened the overall credibility and depth of the study.

This study employed both quantitative and qualitative data analysis techniques to comprehensively interpret the results and validate the effectiveness of the domino-based domino card. Each data set was analyzed based on its type and the research objectives it supported. The quantitative data consisted primarily of students' pretest and posttest scores. These were analyzed using descriptive statistical methods to determine central tendencies, such as the mean and standard deviation, which helped illustrate the general performance of the students. To assess the effectiveness of instructional interventions, inferential statistics were used, specifically paired sample t- tests. These tests were used to examine whether there were statistically significant differences in students' learning outcomes before and after the implementation of the media. The same statistical methods were applied across different mathematical topics, including trigonometry, integer operations, and logarithms. Additionally, questionnaire responses were analyzed quantitatively to capture students' perceptions, motivation, and engagement. Responses were tallied and categorized using frequency distributions and percentage analysis to identify trends and general attitudes toward the learning media. The qualitative data, derived from teacher interviews and classroom observation notes, were analyzed through a thematic analysis approach. The data were carefully coded, categorized, and interpreted to extract recurring themes related to student engagement, collaboration, conceptual understanding, and the integration of Batak cultural values. Observational data supported the interpretation of student behavior and interaction during the learning process, while interview data provided deeper insights into the media'susability and impact from the teacher's perspective.

To enhance the validity and credibility of the results, data triangulation was conducted by cross-verifying findings from multiple sources, including test scores, questionnaires, interviews, and classroom observations. This approach ensured a more comprehensive and reliable understanding of how the domino card influenced students' learning experiences and outcomes.

RESULTS AND DISCUSSION

Contextual Strategy-Based Deep Learning in High School

The implementation of in-depth learning to enhance the Pancasila Student Profile dimension at the high school level has had a significant positive impact. The average posttest score in the experimental group increased significantly compared to the control group, indicating that this approach is effective in fostering holistic student character development. The most significant improvements were seen in the dimensions of critical thinking, independence, and mutual cooperation, which are key indicators of student engagement in meaningful and reflective learning.

The implementation of the Dalihan Na Tolu cultural framework in classroom settings was conducted across seven partner schools in North Sumatra. Students were grouped into teams of six to seven and divided into three sub-groups reflecting the roles of hula-hula, dongan tubu, and boru, as inspired by Batak kinship philosophy (Firmando, 2021; Harianja & Sudrajat, 2021; Mansyuarna et al., 2023; Nwoji et al., 2025). Each sub-group had clearly defined tasks corresponding to data gathering, analysis, and conclusion-making stages. This model promoted equitable participation and structured collaboration.

Each of the three mathematical topics namely trigonometry, integer operations, and logarithms was taught using a contextual and interactive approach that combined visual media with culturally themed domino card games. In the trigonometry lesson, students were introduced to triangle models using digital visual aids that helped them identify and differentiate between the opposite, adjacent, and hypotenuse sides. The domino cards designed for this topic included angle ratios such as sine, cosine, and tangent, as well as triangle properties. During the activity, students were encouraged to collaborate in matching angle values with corresponding sides, promoting both conceptual understanding and teamwork. For integer operations, the domino cards presented various combinations of positive and negative numbers. These cards were linked with contextual representations such as changes in elevation and temperature, helping students relate the arithmetic rules of signed numbers to real-world phenomena. By engaging in gameplay that required them to calculate and interpret operations like addition, subtraction, and multiplication of integers, students developed a more intuitive grasp of number directionality and the role of zero as a reference point. In the logarithm topic, students were introduced to the concept through dynamic visual simulations that demonstrated real-life applications such as sound intensity levels, earthquake magnitudes, and population growth. These simulations were accompanied by domino cards that displayed expressions in both logarithmic and exponential forms. Students were challenged to match each logarithmic expression with its equivalent exponential form, reinforcing their understanding of the inverse relationship between the two. Through this interactive activity, students were able to recognize patterns, convert between forms, and apply the concepts in problem-solving contexts.

Observation data revealed increased engagement and task clarity compared to previous unstructured group activities. Teachers noted that students, especially those who were typically passive, showed higher levels of communication and participation when assigned specific sub-group roles.

Table 2. Student Learning Interest Questionnaire Results

Indicator	Percentage for Each School							Average
	S1	S2	S3	S4	S5	S6	S7	
Feeling happy	82	84	90	80	81	87	89	85
Interest to learn	79	77	87	73	82	72	85	79
Shows attention while studying	76	80	83	76	71	78	82	78
Engagement in learning	59	61	62	76	70	84	80	70

Based on the data in Table 2, the *feeling happy* indicator has the highest average percentage across all schools. This suggests that students generally enjoy the learning process, especially due to the use of new media that many students perceive as a novel experience. Schools like State Junior High School 1 Sosopan and State Vocational High School 1 Sei Rampah, both located in rural areas, show the highest percentages for this indicator. The high levels of enjoyment in these schools may stem from the fact that technology-based learning is still relatively new in these environments, creating a sense of excitement and curiosity. In contrast, urban schools, where digital media is more commonly used in classrooms, show slightly lower percentages due to student familiarity with such tools.

The second indicator, *interest in learning*, also scores highly. This is supported by classroom observations, where students actively asked questions about how to use the digital media, navigate teaching materials, and complete the tasks provided. This indicates that the novelty of the media and the challenge of using it sparked genuine student engagement. Similarly, in the third indicator, *showing attention while studying*, students demonstrated considerable focus during lessons. Notably, State Junior High School 1 Sosopan again showed a high percentage, which may point to a positive correlation between feelings of happiness and increased attention during learning.

However, the *engagement in learning* indicator received the lowest average across the four. It was observed that junior high school students, in particular, showed lower engagement compared to high school students. One possible explanation is that the material involved root operations, which were unfamiliar and challenging for many younger students. This led to some difficulty completing the assignments independently and reviewing the concepts at home. Overall, the use of technology-based visual media and domino learning tools appears to have a positive impact on students' learning interest, especially in increasing enjoyment, attention, and curiosity. This finding is consistent with research by Kim & Ahn (2021), which found that the integration of technology in education can significantly enhance student interest in learning.

The questionnaire results, which assessed student interest across four indicators namely feeling happy, interest to learn, focused attention, and engagement, are presented in Figure 1.

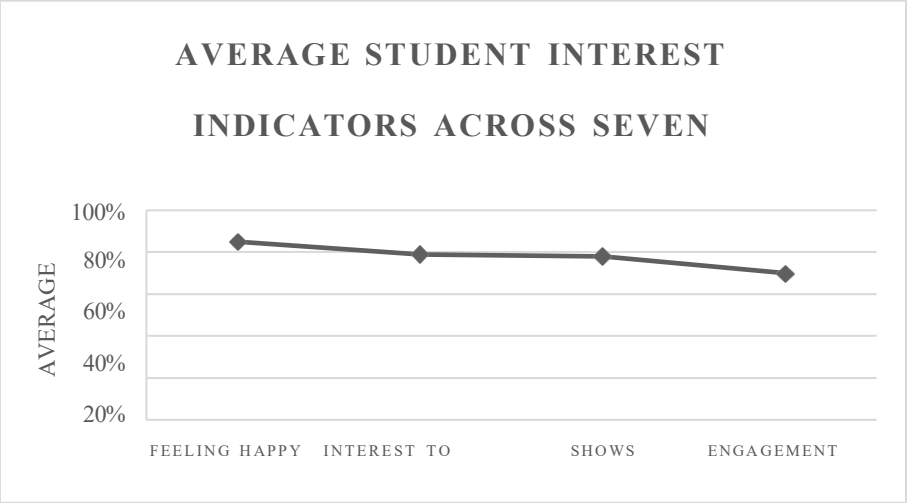

Figure 1. Average Student Interest Indicators Across Seven Schools

Student performance was also evaluated based on the percentage of learners meeting the passing grade criteria in each partner school. These results are detailed in Table 3 and further illustrated in Figure 2 for easier comparison.

Table 3. Level of Learning Completeness Based on Passing Grade for Each Partner School

Partner School	Students Passed	Students Failed	Passing Percentage
S1	20	11	64.52
S2	19	11	63.33
S3	15	6	71.43
S4	22	6	78.57
S5	21	9	70.00
S6	21	8	72.41
S7	27	7	79.41

Based on the data in Table 3, the completion percentage varies across schools, with State Vocational High School 1 Sei Rampah having the highest percentage at 71%. Several factors contributed to this result, including the high level of enthusiasm among students at State Vocational High School 1 Sei Rampah. These students demonstrated a strong interest in the learning materials and actively engaged in discussions, asking questions about both the media used and concepts they did not understand. This

active engagement was also evident during the domino game, where students applied their understanding by commenting on cards that were incorrectly placed by the opposing team. Another contributing factor is that the students at State Vocational High School 1 Sei Rampah are majoring in Informatics, which heightened their interest in the media used. Some students even inquired about how to create the media, further demonstrating their enthusiasm.

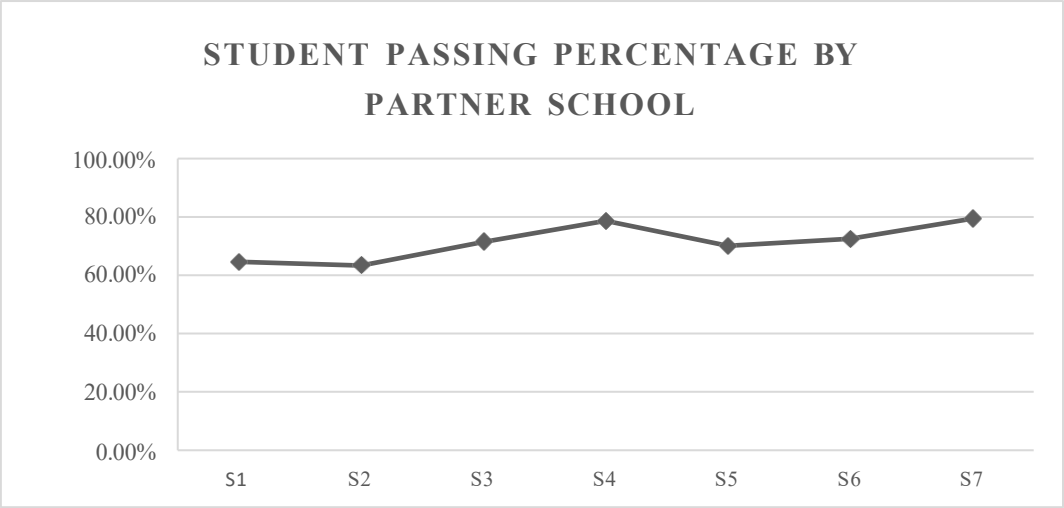

Figure 2. Student Passing Percentage by Partner School

The integration of Batak cultural philosophy through the Dalihan Na Tolu system played a pivotal role in transforming the dynamics of classroom collaboration. Clearly defined sub-group roles based on this traditional kinship model ensured balanced participation and helped students experience social responsibility in learning, particularly essential in character education (Szymkowiak et al., 2021; Azevedo et al., 2023; Nwune et al., 2023; Putri et al., 2025; Roath et al., 2025). This structure significantly reduced passive behavior and improved communication, aligning with Almulla's (2020) findings on project-based learning.

Across the three mathematical domains, trigonometry, integer operations, and logarithms, the use of interactive domino gameplay proved highly effective in overcoming the specific learning challenges associated with each topic. In trigonometry, the use of visual learning tools enabled students to grasp complex geometric relationships in a more concrete manner. Concepts such as the relationship between sides and angles in right triangles traditionally seen as abstract became clearer when students interacted with labeled triangle models and multimedia representations. This finding aligns with research by Lacković (2020) and Liono et al. (2021), who highlight the importance of visualization in clarifying concepts and improving memory retention. The inclusion of culturally relevant visual stimuli, such as using the Bolon house (a traditional Batak structure) as a problem object, enhanced students' spatial reasoning by embedding mathematical ideas within familiar cultural contexts (Hornburg et al., 2021; Somantri, 2024; Sigar et al., 2025). In the case of integer operations, students benefitted from the game-based structure of domino cards, which provided a physical and engaging approach to understanding positive and negative values. Contextual representations such as depicting elevation gains and losses, or temperature changes offered intuitive frameworks for interpreting operations with signed numbers. By associating numerical values with real- world scenarios, students could move beyond symbolic manipulation and instead develop a grounded, conceptual understanding. This was particularly beneficial for junior high school students, who often experience confusion with directionality and the rules of signed operations when taught through conventional methods. As for logarithms, widely regarded as one of the most abstract and challenging topics in mathematics, the learning media succeeded in making the concept more accessible. The domino cards, which required students to match exponential and logarithmic expressions, encouraged active engagement with the underlying structures of these mathematical relationships. These strategies not only improved understanding but also encouraged flexible thinking and pattern recognition, an outcome in line with the findings of Moyer-Packenham et al. (2022), who emphasize the importance of layered cognitive processes in advanced mathematical learning.

In all topics, the domino game format contributed to high engagement and reduced fear of failure. According to Damayanti et al. (2020), such environments are essential for encouraging participation

among shy or reluctant students. Peer correction and friendly competition created space for exploration and independent learning (Ziatdinov & Valles, 2023; Yulisman et al., 2025).

Interest indicators revealed that "feeling happy" scored the highest across all schools. This suggests that novelty, interactivity, and contextual relevance of the materials were key motivators. Furthermore, passing rate data supports the domino card's efficacy, especially in schools with informatics-focused curricula like S7, where students actively explored both the math content and the technology behind the media itself. Ultimately, this study supports Vodă & Florea's (2019) proposition that learning environments should foster both intellectual and character development. By connecting cultural identity with cognitive engagement, this model encourages holistic learning, both academically and socially.

The novelty of this research lies in the integration of local cultural values specifically the Batak philosophy of Dalihan Na Tolu with learning tools such as domino cards to teach abstract mathematical concepts, namely trigonometry, integer operations, and logarithms. While previous studies have explored cultural integration or technological tools separately, this study uniquely bridges the two by embedding cultural kinship roles into collaborative group learning structures and aligning them with topic-specific visualizations and gameplay. This approach not only deepens conceptual understanding but also strengthens students' cultural identity and social-emotional engagement in mathematics learning.

The implications of this study are twofold. Pedagogically, it offers a replicable model for culturally responsive mathematics instruction that fosters student motivation, participation, and conceptual mastery particularly in abstract domains that traditionally challenge learners. Practically, it provides teachers and curriculum developers with a framework for integrating local wisdom into modern teaching methods, reinforcing both educational relevance and cultural preservation. This model can be adapted to various cultural settings and subjects, promoting inclusive and meaningful learning experiences in diverse classrooms.

CONCLUSION

This study successfully developed a Batak culture-based domino card media to enhance students' learning interest and outcomes in three core mathematical topics: trigonometry, integer operations, and logarithms. By embedding the cultural philosophy of *Dalihan Na Tolu* into the design of interactive, visual learning tools, the media provided a contextualized and engaging approach to understanding abstract mathematical concepts. The use of culturally contextualized domino cards improved not only students' comprehension but also their motivation, communication, and collaborative skills. Trigonometric concepts became more accessible through real-world representations such as Batak architecture, while integer operations and logarithmic relationships were clarified using relatable analogies and guided gameplay. The implications of this research suggest that culturally responsive teaching materials can bridge the gap between abstract content and students' real-life experiences. Educators and curriculum developers are encouraged to adopt similar models that leverage local culture to foster deeper learning and character development. Future research may expand this approach to other mathematical domains or cultural contexts, promoting inclusive and meaningful education across diverse student populations.

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AUTHOR CONTRIBUTIONS

Conceptualization, Dedy Juliandri Panjaitan and Firmansyah; Methodology, Dedy Juliandri Panjaitan and Andy Sapta; Validation, Firmansyah, Rima Aprilia, and Annisa Fadhillah Putri Siregar; Formal Analysis, Andy Sapta; Investigation, Firmansyah; Resources, Rima Aprilia; Data Curation, Annisa Fadhillah Putri Siregar; Writing – Original Draft Preparation, Dedy Juliandri Panjaitan; Writing – Review & Editing, Firmansyah; Visualization, Andy Sapta; Supervision, Firmansyah; Project Administration, Dedy Juliandri Panjaitan; Funding Acquisition, Rima Aprilia.

CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declare that no artificial intelligence (AI) tools were used in the generation, analysis, or writing of this manuscript. All aspects of the research, including data collection, interpretation, and manuscript preparation, were carried out entirely by the authors without the assistance of AI-based technologies.

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