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UTILIZATION OF ETHNOMATHEMATICS OF NORTH SUMATERA BATAK CULTURE IN OUT-OF-CLASS MATHEMATICS LEARNING IN ELEMENTARY SCHOOLS

PEMANFAATAN ETNOMATEMATIKA BUDAYA BATAK SUMATERA UTARA DALAM PEMBELAJARAN MATEMATIKA LUAR KELAS DI SEKOLAH DASAR

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Abstract

Elementary school mathematics is often perceived as abstract because it is detached from students' cultural and environmental experiences. Ethnomathematics and outdoor mathematics learning both try to bridge this gap, yet they are rarely studied together. This literature review aims to (1) map the ethnomathematics of the Batak culture of North Sumatra, (2) analyze how well its concepts fit elementary school mathematics, (3) examine the mechanisms and risks of combining it with outdoor learning, and (4) formulate an integration model. Nineteen articles published between 2018 and 2026 were analyzed using content analysis and thematic synthesis. The findings show that ulos cloth, Rumah Bolon, gorga carvings, Gotong and Bulang headwear, Gordang Sambilan, and the Marsitekka game contain concepts of plane figures, solid figures, symmetry, patterns, measurement, and number. The core elementary concepts are plane figures, simple solid figures, measurement, line symmetry, and patterns, whereas transformations, sequences, and trigonometry are enrichment or beyond the level. Existing studies mostly stop at identifying concepts in finished artifacts, and none has tested the combination in classrooms. The analysis yields four mechanisms that may strengthen learning (meaningful context, concrete representation, social interaction, and cultural identity) and five risks (tokenism, subethnic generalization, over-mathematization, mathematical inaccuracy, and level mismatch). The article proposes a four-stage integration model, a five-station Math Trail, a design-quality checklist, and a research agenda. All designs are conceptual and require empirical testing.

Keywords : Ethnomathematics, Batak Culture, Outdoor Learning, Math Trail, Elementary School Mathematics.

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Abstrak

Matematika sekolah dasar sering dipersepsikan abstrak karena terlepas dari pengalaman budaya dan lingkungan peserta didik. Etnomatematika dan pembelajaran matematika luar kelas sama-sama berupaya menjembatani kesenjangan itu, tetapi keduanya jarang dikaji bersama. Studi literatur ini bertujuan (1) memetakan etnomatematika budaya Batak Sumatera Utara, (2) menganalisis kesesuaian konsepnya dengan matematika sekolah dasar, (3) menelaah mekanisme dan risiko memadukannya dengan pembelajaran luar kelas, dan (4) merumuskan model integrasinya. Sebanyak 19 artikel terbitan 2018–2026 dianalisis dengan analisis isi dan sintesis tematik. Hasil menunjukkan bahwa ulos, Rumah Bolon, gorga, Gotong dan Bulang, Gordang Sambilan, dan permainan Marsitekka memuat konsep bangun datar, bangun ruang, simetri, pola, pengukuran, dan bilangan. Konsep inti sekolah dasar adalah bangun datar, bangun ruang sederhana, pengukuran, simetri lipat, dan pola, sedangkan transformasi, barisan, dan trigonometri bersifat pengayaan atau berada di luar jenjang. Kajian yang ada umumnya berhenti pada identifikasi konsep pada artefak jadi, dan belum ada yang menguji perpaduan ini di kelas. Analisis menghasilkan empat mekanisme yang diduga menguatkan pembelajaran (konteks bermakna, representasi konkret, interaksi sosial, dan identitas budaya) serta lima risiko (tokenisme, generalisasi subetnis, matematisasi berlebihan, ketidaktepatan matematis, dan ketidaksesuaian jenjang). Artikel ini mengusulkan model integrasi empat tahap, rancangan Math Trail lima titik, daftar periksa kualitas rancangan, dan agenda riset. Seluruh rancangan bersifat konseptual dan perlu diuji secara empiris.

Kata Kunci : Etnomatematika, Budaya Batak, Pembelajaran Luar Kelas, Math Trail, Matematika Sekolah Dasar.

1. INTRODUCTION

Mathematics plays a crucial role in developing reasoning, problem-solving, and critical thinking skills from elementary school onward. However, mathematics is often taught as a culture-free, symbol- and procedure-oriented discipline, making it seem abstract to students (Ditasona, 2023). In geometry, learning dominated by lectures and practice exercises has been reported to be associated with low motivation and learning outcomes for elementary school students (Pambudi, 2022). Yet, in the Independent Curriculum, geometric elements, along with numbers, algebra, measurement, and data analysis and probability, are core learning outcomes for elementary school mathematics (Head of BSKAP, 2024).

Two approaches offer different but closely related solutions. Ethnomathematics presents culture as a source of context: it examines mathematical ideas, methods, and practices that develop within specific cultural groups (D'Ambrosio, 1985; Rosa & Orey, 2011; Rosa et al., 2016). Out-of-class mathematics learning presents a real-world environment as a learning space, where students observe, measure, and solve problems with real objects (Pambudi, 2022). Both are based on the same belief: that mathematics is more meaningful when rooted in real-life situations (Freudenthal, 1991; Brown et al., 1989), and both converge on a practical issue: cultural artifacts found in the students' environment.

North Sumatra boasts a rich Batak cultural heritage, encompassing several sub-ethnic groups, including the Toba, Karo, Mandailing, and Simalungun (Br Ginting et al., 2024). In recent years, Batak artifacts have been widely explored ethnomathematically, including the ulos (Basmara, 2024; Sartika et al., 2024; Trisiya & Ananda, 2025), the Rumah Bolon (Pane & Sihotang, 2022; Sihombing & Tambunan, 2021), and the gorga (Ditasona, 2023). On the other hand, out-of-class learning in elementary schools shows potential for motivation and geometry learning outcomes (Pambudi, 2022), although results may vary depending on school conditions (Haji et al., 2019).

However, three gaps remain. First, fragmentation: in the articles compiled for this study, explorations of Batak ethnomathematics and out-of-class learning proceed independently, and no studies explicitly link them have been found. Second, depth: ethnomathematics studies generally stop at identifying forms or concepts in artifacts, while rarely examining the suitability of each concept for

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elementary school, the mechanisms that make it useful, and the risks of its implementation. Third, criticism: critical literature warns that using culture as a learning tool can be superficial, uncritical of the culture being studied, or trapped in the assumption that knowledge can simply be transferred from one context to another (Pais, 2011; Vithal & Skovsmose, 1997).

Based on these gaps, this article answers four questions: (1) what are the patterns of findings of ethnomathematics of North Sumatran Batak culture in the literature; (2) which concepts are appropriate for elementary school mathematics and which are merely enrichment; (3) what mechanisms underlie the integration of ethnomathematics with outdoor learning and what risks need to be anticipated; and (4) what integration model and Math Trail design can be derived from this synthesis. The contribution of this article is a synthesis that considers the suitability of levels and criticisms of ethnomathematics, as well as a model and checklist that can be used by elementary school teachers and teacher candidates.

2. RESEARCH METHOD

This study employed a literature review with a qualitative descriptive approach to collect, compare, and synthesize previous research on Batak cultural ethnomathematics and mathematics learning outside the classroom. Searches were conducted through Google Scholar, GARUDA, and scientific journal pages using keywords related to Batak ethnomathematics, Batak culture in mathematics learning, and outdoor mathematics and math trails. Literature was limited to publications published between 2018 and 2026 and selected based on title, abstract, and text availability.

Articles analyzed had to be journals or proceedings with verifiable bibliographic identity, discuss mathematical concepts in Batak culture or mathematics learning outside the classroom, and be written in Indonesian or English. Popular sources and blogs were excluded. Based on these criteria, 19 articles were obtained: 15 articles on Batak cultural ethnomathematics and 4 articles on mathematics learning outside the classroom. Data were extracted based on author, year, cultural object, location or research design, and key findings. Data were then analyzed through data reduction, grouping findings, mapping concepts to elementary school learning outcomes, and identifying mechanisms and the status of evidence.

The validity of the study was maintained through triangulation between sources, verification of bibliographic identity, and the presentation of a source matrix as an audit trail. This study is not a full systematic review because it did not use a registered protocol and formal quality assessment; therefore, the results are a directed synthesis based on literature that meets the research criteria.

3. RESULT AND DISCUSSION

This study analyzed 15 articles on Batak cultural ethnomathematics. Most studies used a qualitative exploratory approach through observation and interviews, while Pane and Sihotang (2022) used a literature review, and Br. Ginting et al. (2024) summarized explorations across various Batak cultures. Ulos and Rumah Bolon are the most widely studied objects due to their diverse shapes, patterns, and geometric elements that can be linked to mathematical concepts. A summary of the sources, cultural objects, and mathematical concepts found is presented in Table 1.

Table 1. Summary of the studied articles on Batak cultural ethnomathematics

No	Source	Cultural objects	Findings of mathematical concepts
1	Lubis dkk. (2018)	Gordang Sambilan (Mandailing)	The concept of geometry and arithmetic sequences
2	Br Ginting dkk. (2024)	Summary of Batak culture (Toba, Karo, Mandailing, Simalungun)	Lines, angles, congruence, plane figures and geometric shapes, geometric transformations, arithmetic sequences, numbers

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No	Source	Cultural objects	Findings of mathematical concepts
3	Sihombing & Tambunan (2021)	Bolon (Toba) House Ornaments, Tobasa Museum	Pentagon, circle, triangle, square, rectangle, cone; reflection and transformation
4	Pane & Sihotang (2022)	Bolon House (Toba), literature review	One, two, and three-dimensional geometry
5	Panjaitan & Ammamiarihta (2023)	Mutual Assistance and Monthly (Simalungun)	Numbers, parallel lines, lines of symmetry, triangles, geometric transformations
6	Ditasona (2023)	Gorga (Toba and Samosir)	Seven types of symmetry: translation, mirroring, vertical, horizontal, 180° rotation, and combinations thereof.
7	Marta & Simorangkir (2023)	Gondang Batak musical instrument	Geometry concepts with the help of GeoGebra; can be used in elementary and middle schools
8	Naibaho dkk. (2024)	Bolon House, Tomok Village, Samosir	Geometric objects in traditional houses
9	Basmara (2024)	Ulos Ragidup (Toba)	Square, equilateral triangle, isosceles triangle, rectangle, rhombus
10	Sartika dkk. (2024)	Ulos Saddum (Toba)	Frieze pattern (symmetry) in the motif; visualization with GeoGebra
11	Mailani dkk. (2025)	Bolon and Ulos House, Central Tapanuli	Two-dimensional forms in ulos motifs, symmetry in traditional houses, geometric patterns in weaving
12	Putri dkk. (2025)	Marsitekka and Bolon House (Toba)	Flat shapes; in Rumah Bolon: isosceles triangle, trapezoid, circle, rectangle
13	Trisiya & Ananda (2025)	Ulos Sadum, Holong, Panssamot (Toba)	Holong: trapezoid, rhombus; Panssamot: pentagon, rectangle, rhombus
14	N. A. Lubis (2025)	Ulos Parompa Sadun (Tapanuli Selatan)	Triangle, square, rhombus, trapezoid; translation, rotation, reflection, dilation
15	Aditiya dkk. (2026)	Rumah Bolon Simalungun	Rectangle, triangle, prism, cylinder, symmetry, proportion, roof slope (trigonometry)

Source: author's analysis of the articles reviewed.

The results of the study indicate a relatively consistent pattern of findings across several cultural objects. For ulos, Trisiya and Ananda (2025) found trapezoids and rhombuses in the ulos Holong, and pentagons, rectangles, and rhombuses in the ulos Panssamot. Basmara (2024) found squares, equilateral triangles, isosceles triangles, rectangles, and rhombuses in ulos Ragidup, while N. A. Lubis (2025) found triangles, squares, rhombuses, trapezoids, and transformations in ulos Parompa Sadun. The rhombus appears in three types of ulos in three different studies and can therefore be viewed as a recurring shape in ulos motifs. In addition to geometric shapes, Sartika et al. (2024) found frieze patterns, or repeating patterns based on symmetry rules, in ulos Saddum.

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In the Rumah Bolon, simple plane and spatial shapes are also found in several studies. Sihombing and Tambunan (2021) found pentagons, circles, triangles, squares, rectangles, and cones in Rumah Bolon ornaments. Pane and Sihotang (2022) summarized one- to three-dimensional geometric concepts, while Naibaho et al. (2024) identified various geometric objects in Rumah Bolon in Tomok Village. Putri et al. (2025) found isosceles triangles, trapezoids, circles, and rectangles on roofs, facades, and ornaments. Meanwhile, Aditiya et al. (2026) found rectangles, triangles, prisms, cylinders, symmetry, proportion, and roof slopes that can be linked to trigonometry in the Simalungun Bolon House. However, proportion and trigonometry were only found in one study and therefore cannot be considered general ethnomathematic characteristics of the Bolon House.

The findings on gorga (ornate carvings) show a distinct character because they relate not only to form but also to the pattern-forming process. Ditasona (2023) found seven types of symmetry in the Toba and Samosir gorga and explained that the carvers used a single basic pattern or mall that was shifted, rotated, or reversed to create motifs. Panjaitan and Ammamiarihta (2023) found concepts of number, parallel lines, line symmetry, triangles, and transformation in Gotong and Bulang. Lubis et al. (2018) found geometric concepts and arithmetic sequences in Gordang Sambilan, while Marta and Simorangkir (2023) explored geometric concepts in Gondang Batak using GeoGebra.

These findings can be understood through three layers of analysis: the artifact's form, its manufacturing or use practices, and its cultural meaning. Most of the research in [Table 1] focuses on the first layer, identifying the mathematical forms and concepts in the artifact. Ditasona (2023) is one of the more in-depth studies, examining the practices of carvers through interviews and observations of maching techniques. Meanwhile, Trisiya and Ananda (2025) connect mathematical concepts in ulos with cultural values such as compassion, protection, and unity. This grouping represents the authors' analytical reading of the articles reviewed.

These differences in depth are important for mathematics learning. The artifact layer can be used for identification and measurement activities, while the practice layer allows students to engage in mathematical activities through constructing or imitating patterns. The cultural meaning layer also helps prevent culture from being merely visual objects. When linked to mathematical activities, Bishop (1988) notes that ulos and gorga are closely related to design activities: Rumah Bolon (a traditional Javanese cloth) with measuring, designing, and determining locations; Marsitekka (a traditional Javanese cloth) with play; and Gordang Sambilan (a traditional Javanese cloth) with calculating and comparing measurements. This mapping shows that measuring and playing activities are relatively underexplored compared to design activities.

In terms of sub-ethnicities, the Toba are the most represented, followed by Simalungun, Mandailing, and the South and Central Tapanuli regions. Karo only appear in cross-cultural studies, while Pakpak are not found in the research corpus. Br Ginting et al. (2024) demonstrated differences between sub-ethnicities, for example, the traditional Simalungun cloth is called hiou and the way the Mandailing wears ulos differs from the Toba. Therefore, the terms "ulos" or "Rumah Bolon" cannot be treated as a uniform form for all Batak sub-ethnicities. The findings of this study also more strongly reflect the Toba context than other sub-ethnicities.

Not all mathematical concepts identified in ethnomathematics research are appropriate for elementary school students. Concept mapping to Learning Outcome (CP) elements and the labeling of core and enrichment concepts are presented in Table 2. Planar shapes, simple geometric shapes, measuring length, circumference, and area, symmetry, repeating patterns, and counting and comparing activities are the most appropriate concepts for elementary school core materials. Geometric transformations and arithmetic sequences are more appropriately positioned as enrichment materials, tailored to the student's developmental level, while proportion and trigonometry fall outside the core elementary school material.

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Table 2. Mapping of Batak ethnomathematics concepts to elementary school mathematics

Mathematical concepts	Cultural objects sources	CP SD Elements	Marking
Flat shapes (triangle, square, rectangle, rhombus, trapezoid, circle)	Ulos, Rumah Bolon, gorga, Marsitekka	Geometri	Elementary school core: recognizing, naming characteristics, and grouping
Simple geometric shapes (cubes, cylinders, cones, prisms)	Rumah Bolon, Gordang Sambilan	Geometri	Elementary school core at the level of recognizing shapes and characteristics
Length, circumference, and area	Rumah Bolon, ulos, area Marsitekka	Pengukuran	Elementary school core: measuring with standard and non-standard units
Fold symmetry and repeating patterns	Ulos, gorga, Gotong dan Bulang	Geometri; aljabar (pola)	SD core at an intuitive level: observing, folding, continuing patterns
Counting and comparing many elements	Motif ulos, Gotong dan Bulang, gendang Gordang Sambilan	Bilangan	SD Core
Geometric transformations (translation, reflection, rotation, dilation)	Gorga, ulos, ornamen Rumah Bolon	Geometri	Enrichment: formal language is generally discussed at higher levels; in elementary school it is sufficient to shift and reflect visually.
Arithmetic sequence	Gordang Sambilan	-	Enrichment: in elementary school it is sufficient as a number pattern and size sequence
Proportion and trigonometry	Rumah Bolon Simalungun	-	Beyond elementary school material

Source: Author's analysis based on the findings in Table 1 and CP elements (Head of BSKAP, 2024). Marking needs to be adjusted to the CP and the learning objectives applicable in the school.

This mapping also demonstrates the importance of using cultural objects concretely. Based on Bruner's (1966) development of representation, cultural objects can be utilized at the enactive and iconic stages through holding, measuring, folding, and drawing activities before students are directed to symbolic representation. Therefore, teachers need to bridge concrete experiences with cultural objects toward the use of mathematical concepts or formulas. Core concepts can be the basis for learning, while enrichment concepts are provided selectively according to students' abilities and needs.

A study of out-of-class mathematics learning was conducted on four articles summarized in Table 3. Haji et al. (2019) found that realistic mathematics learning using an out-of-class approach had a greater impact on productive dispositions in high-stakes schools, while conventional learning was more effective in medium- and low-stakes schools. Hanafiah and Marsigit (2019) demonstrated that out-of-class learning tools for the perimeter and area of squares and rectangles were valid, practical, and effective. Pambudi (2022) found that out-of-class mathematics learning increased

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motivation and geometry learning outcomes and received positive responses from students. Meanwhile, Cahyono and Ludwig (2019) demonstrated that a mobile app-assisted math trail can provide mathematical experiences and improve student performance.

Tabel 3. Ringkasan artikel pembelajaran matematika luar kelas

No	Sumber	Design and subject	Main findings
1	Haji dkk. (2019)	Quasi-experimental; 75 fifth grade students from five elementary schools	Realistic mathematics learning with an outdoor approach has a greater influence on productive dispositions in high-category schools; in medium and low-category schools, conventional learning has a greater influence.
2	Hanafiah & Marsigit (2019)	Device development; grade IV; perimeter and area of squares and rectangles	The tools (RPP, worksheets, teaching materials, tests) were declared valid, practical, and effective; students' cognitive abilities increased at each meeting.
3	Pambudi (2022)	Experiment; 54 fourth grade students at a public elementary school in Jember	Out-of-class mathematics learning methods improve geometry learning motivation and outcomes; student responses are very positive.
4	Cahyono & Ludwig (2019)	Exploratory research in Indonesia; math trail with mobile applications (non-elementary school context)	Technology-assisted extracurricular activities were successfully designed and implemented; students gained mathematical experience and improved performance.

Source: author's analysis of the articles reviewed.

These four studies demonstrate that out-of-class mathematics learning has the potential to support learning, but none have utilized a Batak cultural context. Therefore, the integration of Batak ethnomathematics with out-of-class learning in this study remains hypothetical. The results of Haji et al. (2019) also showed that outdoor learning is not automatically more effective because school conditions also influence outcomes. Meanwhile, research by Pambudi (2022) and Hanafiah and Marsigit (2019) finds common ground with Batak ethnomathematics because they both emphasize geometry and measurement. Barriers such as teacher readiness and school policy support, as found by Fauzi et al. (2026), also need to be considered in its implementation.

Based on the synthesis of theory and research findings, four mechanisms can explain the potential integration of ethnomathematics with outdoor learning: meaningful context, the shift from concrete to symbolic representation, social interaction, and cultural identity and appreciation. Details of the mechanisms, theoretical basis, corpus evidence, and the status of the evidence are presented in Table 4. Meaningful context is supported by Brown et al.'s (1989) theory of situational cognition and Freudenthal's (1991) mathematization, while the shift from concrete to symbolic experience is related to Bruner's (1966) theory. Social interaction is based on Vygotsky (1978), while cultural identity and appreciation are linked to ethnomathematics as a program (Rosa et al., 2016) and values within cultural patterns (Prahmana & D'Ambrosio, 2020).

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Table 4. Mechanism of integrating ethnomathematics and outdoor learning

Mechanism	Basic theory	Evidence in the corpus	Evidence status
Meaningful context	Situational cognition (Brown et al., 1989); mathematization (Freudenthal, 1991)	Learning outside the classroom increases motivation and learning outcomes in geometry (Pambudi, 2022); Ethnomathematical studies suggest the relevance of context, but do not measure impact	Indicative for outside the classroom; not tested for the Batak context
Concrete to symbolic representation	Enaktif, ikonik, simbolik (Bruner, 1966)	The outdoor device for circumference and area was declared valid, practical, and effective (Hanafiah & Marsigit, 2019)	Indikatif
Social interaction	Learning as a social process (Vygotsky, 1978)	There is no specific evidence in the corpus; group work is a Math Trail design choice in this article.	Not yet tested
Cultural identity and appreciation	Ethnomathematics as a program (Rosa et al., 2016); values in cultural patterns (Prahmana & D'Ambrosio, 2020)	Ditasona (2023) and Aditiya et al. (2026) suggest the potential to foster cultural appreciation, but do not measure it.	Not yet tested

Source: author's analysis. "Indicative" means there is at least one empirical study in the corpus; "untested" means none.

The current state of evidence indicates that only two mechanisms are indicative, with the other two remaining untested. This suggests that the benefits of combining ethnomathematics and outdoor learning cannot yet be viewed as causal evidence. Meaningful contexts can provide students with reasons to measure and draw, while measuring and drawing activities can serve as a bridge to mathematical symbols. Conversely, social interaction and cultural appreciation depend heavily on task design and the involvement of cultural sources, not solely on the presence of cultural objects.

The implementation of this combination also carries several risks, formulated based on critiques of ethnomathematics by Pais (2011), Vithal and Skovsmose (1997), and findings from the research corpus. These risks and mitigation strategies are presented in Table 5. These risks include tokenism, sub-ethnic generalization, over-mathematization, mathematical imprecision, and level mismatch. Tokenism occurs when culture is simply used as a background image without changing mathematical activities, while generalization occurs when Batak culture is perceived as uniform despite differences between sub-ethnicities. Over-mathematization occurs when artisan practices are given formal mathematical terms that are not actually used in their practice.

Table 5. Implementation risks and their mitigation

Risk	Explanation	Mitigation
Tokenisme	Culture only becomes a background image or introduction, while the mathematical task remains unchanged; ethnomathematics is reduced to a ready-to-use tool (Pais, 2011)	Mathematical goals are set in advance, tasks can only be done by observing objects, and reflection includes cultural aspects.

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Risk	Explanation	Mitigation
Generalisasi subetnis	"Batak culture" is treated as uniform, even though sub-ethnicities differ in their traditional cloth, clothing, and houses (Br Ginting et al., 2024); culture can be used as a context without critical examination (Vithal & Skovsmose, 1997).	Mentioning the type and sub-ethnic origin of the object; using local objects; involving local sources
Overmathematization	The artisans' practices are adhering to formal terms that they do not use; gorga carvers work with mals practically (Ditasona, 2023)	Distinguishing artisan practices from the mathematical terms teachers use to describe them
Mathematical imprecision	Woven motifs and handmade carvings only approximate the ideal shape, and naming the shapes depends on the researcher's interpretation	Checking the properties of shapes (sides, angles) through measurements and accepting tolerances; teachers verify concepts before use.
Level mismatch	Concepts such as trigonometry, sequences, and formal transformations are carried over to elementary school without adjustment.	Using Table 2 mapping; the enrichment concept is optional

Source: author's analysis.

The risk of mathematical imprecision also requires attention because woven motifs and handmade carvings do not always conform to ideal geometric shapes. Therefore, the properties of shapes need to be examined through measurement, and teachers need to verify concepts before using them in learning. Meanwhile, concepts such as trigonometry, sequences, and formal transformations should not be directly introduced to elementary school students without adjustment. The distinction between artisan practices and mathematical terms also needs to be maintained because artisans work based on patterns, manual habits, and aesthetic values, rather than formal geometric definitions. This does not diminish the learning value, but helps maintain conceptual accuracy and prevent overstated claims about cultural practices.

Based on these mechanisms and risks, the integration model was developed through four interconnected stages: establishing mathematical objectives, selecting and verifying cultural objects, designing layered tasks, and conducting two-way reflection. The teacher first determines the learning objectives for geometry, measurement, numbers, or patterns. Next, cultural objects are selected based on their availability in the students' environment, taking into account their type, sub-ethnic origin, and meaning. Tasks are then designed, ranging from observing and identifying, measuring or counting, to reasoning and explaining. The final stage involves reflecting on mathematical concepts as well as students' knowledge and attitudes toward culture.

The five-point Math Trail design based on Batak culture is presented in Table 6, which includes ulos, gorga, Rumah Bolon, Marsitekka, and Gordang Sambilan. On ulos, students can observe motifs, group plane shapes, count pattern repetitions, and test symmetry. In the gorga, students can identify the basic pattern or mal, copy it on grid paper, then continue the pattern through shifting and mirroring. In the Rumah Bolon, students can identify the shape of the roof or facade and measure length and circumference. Marsitekka can be used to observe the shape of the square, measure sides, count the number of squares, and play, while Gordang Sambilan can be used to sort and compare the sizes of

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drums and find the sequence pattern. This design is the result of a synthesis of literature and has not been empirically tested.

Table 6. Five-point Math Trail design based on Batak culture

Points and objects	Student activities	Mathematical concepts	Product
1. Ulos (cloth, replica, or photo of motif)	Observing motifs, grouping flat shapes, counting the repetition of motifs in one row, and folding paper replicas of motifs to test symmetry.	Flat shapes, patterns, line symmetry, numbers	Observation table
2. Gorga (on traditional houses, churches, or other buildings, or photos)	Finding basic motif units (mal) and how to arrange them; copying the mal on grid paper then continuing the pattern by shifting and mirroring it	Patterns, symmetry, visual reflection	Pattern sketch and pattern letter code
3. Bolon House (visit, museum, or replica)	Identify triangles, trapezoids, and rectangles on a roof or facade; measure the length and width of a panel or step; calculate its perimeter	Flat shapes, measuring length, circumference	Measurement and calculation sheets
4. Marsitekka (school yard)	Draw the playing area with chalk, observe the shape of the squares, measure the sides, count the number of squares, then play.	Flat shapes, measurement, numbers	Floor plan and answers
5. Gordang Sambilan (replica, audio-visual, or studio)	Rank the nine drums from smallest to largest, compare their height and diameter, and mencari pola urutan ukuran	Comparison of size, order, number patterns	Sequence diagram

Source: author's design based on literature synthesis. This design has not been empirically tested.

The Math Trail can be implemented through preparation, implementation, and follow-up stages. Preparation includes setting objectives, verifying cultural origins with resource persons, site surveys, obtaining permits, providing measuring tools and worksheets, forming groups, and providing alternatives in the form of photos, videos, or replicas if a visit is not possible. Implementation begins with an orientation and explanation of ethics, followed by group rotation at five points and presentations. After the activity, students reflect on the mathematical and cultural concepts they encountered. Assessment includes conceptual understanding through worksheets and presentations, process skills through teacher observation, and cultural respect through student reflection.

To maintain design quality, a checklist covering alignment of objectives, mathematical accuracy, cultural authenticity, task meaningfulness, layered tasks, ethics and safety, and differentiation is presented in Table 7. From an ethical perspective, ulos, which has traditional significance, should not be used as a plaything; therefore, folding or cutting activities should use paper or cloth replicas for practice. Permission and involvement of traditional leaders or carvers are also required prior to the activity. Ditasona (2023) showed that gorga have been found in markets, government offices, and places of worship, making them relatively easy objects of observation.

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However, the sculptors are more difficult to find, and therefore, the involvement of informants needs to be planned from the outset.

Table 7. Checklist for the quality of out-of-class ethnomathematics designs

Aspect	Examiner's questions
Alignment of goals	Does each assignment address specific learning objectives and CP elements?
Mathematical precision	Are the forms and concepts mentioned correct, appropriate to the level, and have they been checked through measurement or observation?
Cultural authenticity	Are the type, sub-ethnic origin, and meaning of the object described correctly, and were the sources involved?
Meaningfulness of the task	Can the assignment only be done by observing or measuring real objects, and not just replacing the image in a regular question?
Layered tasks	Are there any tasks to identify, measure or count, and reason or explain?
Ethics and safety	Is permission obtained, objects of traditional significance treated respectfully, and the location safe for students?
Differentiation	Are there any task variations for phases B and C as well as optional enrichment tasks?

Source: author's design based on Table 2 and Table 5.

In terms of implications, the integration model and checklist can be used by elementary school teachers and prospective teachers as a basis for developing contextual mathematics learning based on local culture. For schools and policymakers, the findings of Fauzi et al. (2026) regarding teacher readiness and policy support indicate the need for adequate training and planning time. For researchers, the next challenge is to expand the study from identifying concepts in artifacts to empirically testing their impact on learning.

This study has limitations because the literature corpus is not intended to be comprehensive, so there may still be relevant research that has not been captured. Furthermore, most ethnomathematics research is exploratory in nature, focusing more on demonstrating the potential of concepts than on their impact on student learning. The Math Trail model and design developed have also not been tested in the classroom, while the labeling of core and enrichment concepts, as well as the status of evidence, are analytical considerations for the authors. Based on these limitations, a further research agenda regarding the effectiveness of Math Trail, the validity and practicality of the tools, cultural appreciation, teacher readiness, and differences in outcomes based on school conditions and sub-ethnicity is summarized in Table 8.

Table 8. Further research agenda

Research questions	Suggested design	Indikator
Does the Batak culture-based Math Trail improve elementary school students' understanding of geometry and measurement?	Quasi-experimental or classroom action research	Test of understanding of flat shapes, symmetry, circumference
Is the Math Trail tool valid and practical?	Development research	Validation of mathematicians and culture; practicality according to teachers

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Research questions	Suggested design	Indikator
Does the activity strengthen cultural appreciation?	Mixed methods	Attitude questionnaire, student reflection, observation
How is teacher readiness and what are the obstacles to implementation?	Case study	Planning interviews and observations
Do the results differ according to school conditions and sub-ethnicity of the subjects?	Multi-school quasi-experiment	Comparison of results between school categories (Haji et al., 2019)

Source: author's design.

4. CONCLUSION

Based on 19 articles reviewed, Batak culture in North Sumatra incorporates diverse ethnomathematics in ulos, Rumah Bolon, gorga, Gotong and Bulang, Gordang Sambilan, and the Marsitekka game. The most convergent findings are found in the plane figures in ulos and Rumah Bolon. Existing studies generally focus on finished artifacts, with the Toba being the most represented sub-ethnic group. Therefore, further research into manufacturing practices, cultural meanings, and other sub-ethnic groups is needed.

Concepts relevant to elementary school mathematics include plane figures, simple solid figures, measurement, lines of symmetry, and repeating patterns. Geometric transformations and arithmetic sequences are more appropriate for enrichment, while proportion and trigonometry fall outside the scope of elementary school.

The integration of ethnomathematics and outdoor learning is supported by four theoretically plausible mechanisms, but only two have indicative evidence, and none have been tested in the Batak context. Five risks tokenism, sub-ethnic generalization, over-mathematization, mathematical imprecision, and grade mismatch need to be addressed. The four-stage integration model, the five-point Math Trail, and the proposed quality checklist can help teachers design instruction that remains centered on mathematical objectives and respects cultural context.

It is recommended that future researchers develop and validate the Batak culture-based Math Trail tool, test it through an appropriate design (Table 8), and expand the study to include artifact-making practices and underrepresented sub-ethnicities, such as the Karo and Pakpak. Teachers can adapt this design to cultural objects available in their respective schools.

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