

Research Article

Human Logical Thinking in Mathematical Concepts: The Ethnomathematics of Batak Mandailing and Batak Toba Ulos

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Abstract: In ethnomathematics, mathematics is not merely a discipline concerned with abstract formulas and theories, but also a social practice closely connected to cultural and historical contexts. Mathematical concepts emerge from human activities, traditions, and logical reasoning developed within society. This study aims to analyze the influence of human logical thinking on the use of mathematical concepts in culture; to identify aspects of logical thinking relevant to ethnomathematics; and to explain the relationship between logical thinking and the development of mathematical concepts in society, particularly within Batak Mandailing and Batak Toba cultural traditions. This study employed a qualitative approach using a literature review method by examining various scholarly sources related to ethnomathematics, culture, and mathematical cognition. The findings reveal that human logical thinking strongly influences the application of mathematical concepts in cultural practices through pattern recognition, classification, spatial reasoning, and problem-solving processes. In Batak Mandailing and Batak Toba cultures, ethnomathematical elements are reflected in *ulos* weaving motifs, traditional architecture, kinship systems, ceremonial arrangements, and community activities. These cultural practices demonstrate mathematical ideas related to geometry, symmetry, measurement, proportion, and classification. Furthermore, logical thinking plays an important role in formulating, interpreting, and preserving mathematical knowledge across generations through cultural transmission.

Keywords: human logical thinking; mathematical concepts; ethnomathematics

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1. Introduction

Ethnomathematics is a branch of science that focuses on the relationship built between mathematics and culture. Ethnomathematics recognizes that mathematics, in addition to being a formal discipline related to applications that benefit daily life, is also a part constructed from human life and culture (Baker, 2022). Ethnomathematics is connected to the study of community life that uses and develops mathematical concepts in their cultural context (D'Ambrosio, 2018). Generally, ethnomathematics is formed by two words: "ethno," meaning ethnicity or culture, and "mathematics," which is a science oriented towards patterns, structures, and quantitative objects (Mania & Alam, 2021). In ethnomathematics, mathematics is not only a science studying abstract formulas and theories but also a social practice linked to specific cultural and historical contexts (Cimen, 2014). Ethnomathematics focuses on understanding how societies use concepts identical to mathematics that are created, developed, and utilized for daily life (Nur et al., 2021). For example, in certain cultures, traditional societies may have a counting system different from the formal mathematical concepts learned in schools. Humans can apply calculation methods based on practical activities and experiences, such as using fingers or specific objects in their environment (Baker, 2022).

Ethnomathematics is related to these counting systems and examines the human logic behind them. Furthermore, ethnomathematics is also concerned with societies that develop unique mathematical concepts in building their own culture (Zhang & Zhang, 2010). For example, in some cultures, there are concepts identical to mathematics applied in life, such as traditional measurement systems or calculation methods used in agriculture.

Ethnomathematics explains these concepts and examines their development within a specific cultural context. Ethnomathematics also examines the influence of mathematical concepts on a society's culture (Anderson-Pence, 2013). In various cultures, mathematical symbols have not only symbolic meanings but also profound spiritual significance. And ethnomathematics studies these meanings and analyzes how mathematical concepts can build cultural identity and belief systems (Baker, 2012). Research in ethnomathematics uses several methods to study the relationship between mathematics and culture, including ethnographic methods, content analysis methods, and interview methods (Kühn, 2017). The ethnographic method is used to collect, document, and observe mathematical practices that develop in a particular culture (D'Ambrosio, 2018). The content analysis method analyzes cultural texts related to mathematical concepts, such as folktales or traditional songs (Umbara et al., 2026). The interview method is used to gain a deeper understanding of the perception and utilization of concepts identical to mathematics within a particular culture.

Within the context of ethnomathematics, there remains a significant research gap regarding the understanding of human thinking logic. In this study, the main focus is understanding how specific communities or groups use mathematical concepts in daily life (D'Ambrosio, 2018). The primary aspect focused on in this ethnomathematics research is human thinking logic. Human thinking logic is the way individuals or groups think to understand and solve problems using mathematical concepts in a cultural context (Umbara et al., 2026). Research focusing on human thinking logic in ethnomathematics is still limited. One reason for this gap is the complexity and diversity of human cultures worldwide. Each cultural group has unique methods or ways of using mathematical concepts in daily life, and human thinking logic can differ between each community group (Solares-Rojas et al., 2026). Therefore, in-depth and comprehensive research is needed to understand human thinking logic within ethnomathematics. Ethnomathematics is still considered a relatively new field that has not been extensively studied. This can potentially hinder research development aimed at understanding human thinking logic in ethnomathematics. Several studies have shown unique patterns in mathematical thinking styles across different cultures (Umbara et al., 2025). In some cultures, mathematical concepts can be conveyed through stories or songs, while in others, they are conveyed through symbols or ritual practices.

The research questions formulated in this study are: (1) How is the relationship between human thinking logic and the development of mathematical concepts in society? (2) How does human thinking logic influence the use of mathematical concepts in culture? and (3) What are the aspects of human thinking logic relevant to the ethnomathematics context? Based on these questions, the objectives of this research are: (1) to explain the relationship between human thinking logic and the development of mathematical concepts in society; (2) to analyze the influence of human thinking logic on the use of mathematical concepts in culture; and (3) to identify aspects of human thinking logic relevant to the ethnomathematics context.

Achieving these objectives is expected to provide the following benefits, in particular offering new insights into the relationship between human thinking logic and the development of mathematical concepts in society; providing a deeper understanding of how human thinking logic influences the use of mathematical concepts in culture; and helping identify aspects of human thinking logic relevant to ethnomathematics. This research is expected to contribute to a broader understanding of the diversity and complexity of mathematical thinking across different cultural contexts. A deeper understanding of human thinking logic in ethnomathematics can enhance appreciation of cultural diversity while enriching mathematics as a discipline closely connected to everyday life and society. Furthermore, this study seeks to explain how thinking logic and mathematical concepts evolve alongside cultural development and daily human activities. Previous studies have shown that ethnomathematics demonstrates the reciprocal relationship between culture and mathematics, where cultural practices shape mathematical concepts and mathematical ideas, in turn, influence cultural development. Such understanding is expected to strengthen awareness of the diversity and complexity of mathematics across different cultural and social contexts.

2. Materials and Methods

This study employs a qualitative research approach with a literature review method (also known as library research). This approach is chosen because the research aims to explore, interpret, and construct an in-depth understanding of the relationship between human logical

thinking and mathematical concepts embedded in the cultural practices of Batak Mandailing and Batak Toba societies. A qualitative literature review allows researchers to synthesize existing knowledge, identify gaps, and develop a comprehensive conceptual framework without directly collecting primary data from the field.

2.1. Research Design

The research design utilized is a qualitative descriptive-interpretive design. This design is focused on describing the characteristics of a phenomenon and interpreting the meaning behind those characteristics based on the analyzed literature. In this context, the phenomenon studied is ethnomathematics, specifically how logical thinking is manifested in the cultural artifacts and activities of the Batak Mandailing and Batak Toba communities.

The research process involved several systematic stages. It began with the formulation of the main research questions, which provided direction for the literature search and subsequent analysis. A systematic search for relevant literature was then conducted using predefined keywords and appropriate academic databases. The collected sources were screened and filtered according to their relevance, credibility, and contribution to addressing the research questions. The selected literature was subsequently analyzed through careful reading, coding, and categorization to identify recurring themes, patterns, and relationships. Finally, the synthesized findings were interpreted in relation to the research questions, allowing conclusions to be drawn and a comprehensive understanding of the research topic to be developed.

2.2. Data Sources and Samples

The primary data source for this literature study is secondary data in the form of scientific documents. The samples in this research are the selected literature units that meet the inclusion criteria. The selection of literature was conducted using a purposive sampling technique to ensure that the sources were relevant and contributed significantly to the research objectives.

The literature was selected according to clearly defined inclusion criteria. Sources were required to be directly relevant to ethnomathematics, human logical thinking, mathematical concepts embedded in cultural practices, or, more specifically, the Batak Mandailing and Batak Toba cultures. Particular attention was given to the credibility of the sources, with preference given to peer-reviewed academic journals, scholarly books published by reputable publishers, and official cultural documentation. The temporal scope primarily covered literature published between 2016 and 2026 to ensure that the review reflected recent developments in the field. However, seminal theoretical works, particularly those associated with D'Ambrosio and the development of ethnomathematics, were also included to establish a strong conceptual foundation.

The literature included several types of sources to provide both theoretical and cultural perspectives on the research topic. Scientific articles constituted a substantial part of the reviewed material, including studies by D'Ambrosio (2018), Orey and Rosa (2021), Sunzuma and Umbara (2025). Books and book chapters addressing ethnomathematics, the philosophy of mathematics, and cognitive psychology were also incorporated, including works by Tall (2013) and Cellucci (2013). In addition, cultural documentation was consulted to provide contextual information about Batak culture, particularly traditional architecture, *ulos* weaving, and kinship systems. These materials included documentation produced by the Department of Culture and Tourism of North Sumatra.

2.3. Data Collection Techniques

Data collection was carried out using the documentation technique. The research team systematically searched for, collected, and reviewed various written and digital documents. The literature search was conducted using electronic academic databases and scholarly search platforms, including Google Scholar, Scopus, ResearchGate, and university digital libraries. The search strategy employed combinations of keywords such as "ethnomathematics," "human logical thinking," "mathematical concepts," "Batak Mandailing," "Batak Toba," "ulos," "cultural mathematics," and "indigenous knowledge." The titles and abstracts of the retrieved publications were initially screened to determine their relevance to the research topic, while irrelevant and duplicate records were excluded. Full texts of potentially relevant publications were then obtained for more detailed examination. Each selected source was systematically reviewed, with key information extracted concerning research objectives, theoretical frameworks, methodologies, major findings, and conclusions, particularly those addressing logical thinking, cultural practices, and mathematical concepts. The extracted

information was subsequently recorded and organized according to relevant themes and categories, while reference management software was used to facilitate the organization of sources and ensure accurate attribution.

2.4. Data Analysis Technique

Data analysis in this literature study was conducted using a qualitative thematic analysis approach. This technique was chosen because it allows the researcher to identify, analyze, and report patterns (themes) within the collected data. The analysis followed the systematic thematic analysis approach proposed by Braun and Clarke (2006).

The researchers first familiarized themselves with the collected literature by reading and rereading the selected sources to develop a comprehensive understanding of their content, arguments, and underlying ideas. Relevant passages and concepts concerning logical thinking, ethnomathematics, Batak culture, and mathematical concepts were then identified and assigned initial codes. For instance, discussions of repetitive geometric patterns in *ulos* were coded as “Pattern Recognition,” whereas descriptions of kinship systems were categorized as “Social Structures.”

The initial codes were subsequently compared and grouped into broader themes according to conceptual similarities. Codes such as “Pattern Recognition,” “Symmetry,” and “Arithmetic Sequences,” for example, were integrated into the broader theme of “Patterns and Relationships.” The emerging themes were reviewed and refined to ensure internal coherence, clear distinctions between themes, and adequate representation of the literature. Each theme was then clearly defined and named in accordance with the research objectives and the conceptual patterns identified during the analysis.

The final thematic structure encompassed three principal themes: the relationship between human logical thinking and the development of mathematical concepts; the influence of logical thinking on the use of mathematical concepts in culture; and aspects of human logical thinking within the ethnomathematical context. The latter theme was further organized into the subthemes of patterns and relationships, systems and structures, and problem solving. Finally, the findings were synthesized into a coherent narrative supported by evidence and references from the reviewed literature. The resulting themes were interpreted in relation to the research questions to generate conclusions regarding the relationships among logical thinking, mathematical concepts, and cultural practices.

3. Results

3.1. Relationship between Human Thinking Logic and the Development of Mathematical Concepts

The relationship between human thinking logic and the development of mathematical concepts in society is very close and mutually influential. Human thinking logic is the ability to use common sense, understand cause-and-effect relationships, and draw conclusions based on systematic and consistent thought patterns. Mathematical concepts are the language used to describe and model these patterns. Human thinking logic serves as a fundamental basis for the development of mathematical concepts (Cellucci, 2013). Logic helps the process of understanding basic mathematical principles like the connection between numbers, mathematical operations, and existing patterns (Baker, 2012). For example, when learning about integers, human thinking logic helps us better understand the concepts of addition, subtraction, multiplication, and division, which are the foundations of mathematics.

Human thinking logic also facilitates the understanding of formal logic concepts used in mathematics. Concepts such as deduction, induction, and other logical reasoning help in better understanding and applying mathematical principles (Goranko, 2016). Human thinking logic makes it easier for us to recognize patterns, formulate hypotheses, and test the truth of a mathematical statement. Conversely, the development of mathematical concepts also influences human thinking logic (Nasrum et al., 2025). Through mathematics, various logic concepts are learned, including systematic ways of thinking. For instance, in learning algebra, we learn about solving equations and applying logic to identify correct solutions. These mathematical concepts help us develop critical, analytical, and problem-solving thinking skills.

In society, human thinking logic and the development of mathematical concepts complement each other (Bielaczyc et al., 2013). Human thinking logic is useful in various fields, such as science, technology, economics, etc., to solve complex problems and make rational decisions (Machaba & Dhlamini, 2021). Continuously developing mathematical concepts also provide a strong foundation for the advancement of science and technology. For example, in computer science, human thinking logic is useful for algorithm and

programming development (Mabotja, 2026). Concepts like propositional logic and set theory are used for modeling and problem-solving in the computing world. Without human thinking logic, mathematical concepts in computing could not be applied effectively. In economics, human thinking logic is useful for data analysis, decision-making, and strategic planning (Bryson et al., 2018). Mathematical concepts like statistics and optimization theory are used to model and predict market behavior and optimize business decisions. Human thinking logic can be used to understand and apply mathematical concepts in an economic context.

Thus, the relationship between human thinking logic and the development of mathematical concepts is crucial for societal progress. Human thinking logic serves as the basis for understanding and applying mathematical concepts, while the development of mathematical concepts provides a strong foundation for science and technology (Mabotja, 2026). By understanding how to use human thinking logic and develop mathematical concepts, we can create innovative solutions, make better decisions, and contribute to overall societal advancement. In developing mathematical concepts, human thinking logic plays a vital role. Logic helps us understand basic mathematical principles and build a solid understanding of the relationships between numbers, operations, and patterns (Ferreirós, 2015). A fundamental principle is the relationship between number objects. Human thinking logic allows us to understand basic concepts like integers, fractions, decimals, etc. Using logic, we understand how these numbers relate and how they are used in operations like addition, subtraction, multiplication, and division.

Human thinking logic also helps build an understanding of mathematical operations themselves. Logic allows us to understand basic principles like commutativity, associativity, and distributivity (Hilbert & Ackermann, 2022). With this understanding, we can use mathematical operations correctly and effectively. Patterns are also an important part of mathematical concepts. Human thinking logic helps recognize patterns in number sequences, number series, and geometric shapes (Gadong, 2025). Using logic, we can identify these patterns and use them to predict subsequent numbers or solve mathematical problems formed by these patterns. Without logic, mathematical concepts would be difficult to understand and apply effectively and efficiently (Alangui, 2017). Human thinking logic forms the necessary framework for understanding and correctly applying mathematical concepts. Without logic, we tend to see numbers merely as meaningless symbols and are less able to understand the relationships between them.

Human thinking logic also helps us develop critical and analytical thinking skills (Halpern, 2014). In studying mathematics, we are often faced with problems that require logical and systematic solutions. Human thinking logic enables us to solve problems by understanding the information given, identifying patterns, and using relevant mathematical principles (Gadong, 2025). This skill is highly beneficial for daily life, not only in mathematics but also in various other fields. The development of mathematical concepts also affects human thinking logic. Through mathematics, we learn various logic concepts such as deduction, induction, and other logical reasoning. These concepts help develop critical and analytical thinking skills applicable in many life aspects.

One important logic concept in mathematics is deduction. Deduction is the process of drawing logical conclusions based on given premises. In mathematics, deduction proves the truth of a mathematical statement using established logical rules (Nugraha & Nugraha, 2025). This process involves systematic and consistent thinking, identifying patterns, and understanding logical relationships between mathematical concepts. Through practice with deduction in mathematics, we can develop critical thinking skills to identify logical fallacies and gain a deep understanding of mathematical concepts (Dahlana et al., 2019).

Besides deduction, another important logical concept is induction. Induction is drawing general conclusions based on observed patterns. In mathematics, induction proves the truth of a mathematical statement that applies to all members of a set (Weber et al., 2014). This process involves creative thinking to identify occurring patterns and the ability to generalize them (Gadong, 2025). The concept of induction in mathematics helps develop analytical thinking skills to identify underlying patterns in mathematical concepts and understand generally applicable principles.

Beyond deduction and induction, other logical concepts in mathematics help develop critical and analytical thinking (Nugraha & Nugraha, 2025). For example, logical reasoning involving understanding of implication, contradiction, and contraposition. These concepts help us understand logical relationships between mathematical statements and identify logical errors in mathematical problem-solving. Through understanding and applying logic concepts in mathematics, we can develop critical and analytical thinking skills that positively impact

various aspects of our lives (Teke & Şahin, 2025). Critical thinking allows us to analyze problems carefully, identify underlying assumptions, and draw rational conclusions. Critical and analytical thinking developed through mathematics is also applicable outside mathematics (Payadnya et al., 2024). For instance, in science, technology, and engineering, these skills are crucial for analyzing data, designing experiments, and developing solutions to complex problems. In business and economics, they help analyze markets, identify opportunities, and make data-driven decisions (Risdiyanti et al., 2024). Thus, through mathematics and its embedded logic concepts, we can develop highly valuable critical and analytical thinking skills, benefiting not only our understanding and use of mathematical concepts but also various other life aspects.

Continuously evolving mathematical concepts also provide a strong foundation for the development of science and technology. Mathematics is a universal language used to describe natural phenomena, analyze data, and model complex systems (Sayama, 2015). In science, mathematics is used to formulate, measure, and predict natural phenomena, and develop theories underlying our knowledge of the universe. In technology, mathematics is used to design computer systems, optimize algorithms, and develop advanced technologies like artificial intelligence and quantum computing (Teke & Şahin, 2025).

The development of mathematical concepts also positively impacts daily life. Concepts like calculation, measurement, and statistics are used in finance, business, and management to make estimates, manage risk, and make decisions based on accurate data and analysis (Alangui, 2017). Mathematics is also used in architectural and engineering design to calculate structural strength, design efficient buildings, and optimize resource use (Payadnya et al., 2024). Even in everyday life, we use mathematical concepts like counting money, scheduling, and measuring time. Furthermore, human thinking logic and mathematical concept development mutually influence the development of artificial intelligence and computing (Teke & Şahin, 2025). Human thinking logic is the basis for algorithm and computer programming development. Mathematical concepts like propositional logic, set theory, and Boolean algebra are used in modeling and analyzing computer systems (Mabotja, 2026). Conversely, the development of AI and computing also contributes to developing human thinking logic by expanding human ability to solve problems and make decisions.

Figure 1 shows the relationship between thinking logic, culture, and mathematical concepts. It is obvious that this relationship is crucial for advancing society while preserving existing culture. To add, human thinking logic is used in various fields to solve complex problems and make rational decisions, both from the perspective of mathematical concepts integrated into a culture and modern mathematical concepts. Continuously developing mathematical concepts provide a strong foundation for scientific and technological advancement.

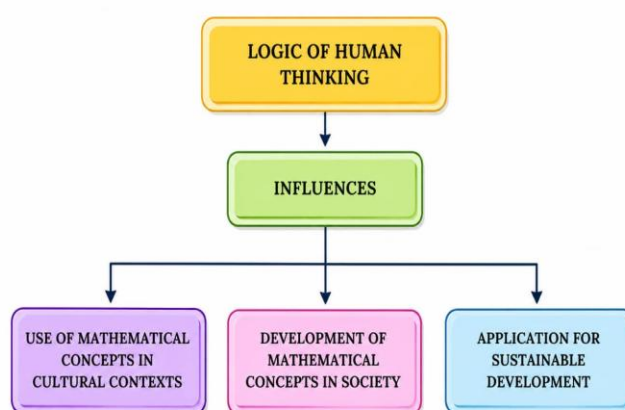


Figure 1. The relationship between thinking logic, culture, and mathematical concepts.

Human thinking logic significantly influences the use of concepts identical to mathematics in developing cultures (van Oers, 2002). Human thinking logic is the human ability to utilize rational and consistent rules and patterns of thought to solve a problem (Paul & Elder, 2019). In the cultural context related to mathematics, human thinking logic plays an important role in several aspects.

3.1.1. Development of Mathematical Concepts

Human thinking logic contributes significantly to the development of mathematical concepts (Tall, 2013). Through logic, humans can recognize patterns, relationships, and mathematical structures that underlie these concepts. Thinking logic helps humans understand how mathematical concepts relate to each other and how they can be applied in various contexts (Jeannotte & Kieran, 2017). First, human thinking logic influences how mathematical concepts are developed. In developing mathematical concepts, logic helps us understand patterns and relationships within data or observed phenomena. For instance, when developing the concept of numbers, logic helps recognize addition and subtraction patterns, allowing us to develop number concepts or related operations (Risdiyanti et al., 2024). Thinking logic helps identify relationships between complex mathematical concepts, such as the relationship between geometry and algebra. Consequently, human thinking logic also influences how we understand mathematical concepts. Logic helps see the overall picture and relationships between mathematical concepts consistently and rationally (Kalchman et al., 2001). For example, in understanding fractions, logic helps identify division patterns and part-whole relationships, enabling a better grasp of fractions.

Human thinking logic influences how we apply mathematical concepts in various fields (Engelbrecht et al., 2020). Logic helps use mathematical concepts to solve problems, make decisions, and take rational actions. In a cultural context, using mathematical concepts based on human thinking logic aids in planning, measuring, managing resources, and solving complex problems (Jeannotte & Kieran, 2017). For example, in economics, logic helps use mathematical concepts like percentage calculation, probability, and statistics related to economic data analysis and data-driven decision-making.

Human thinking logic also influences how we interpret and communicate mathematical concepts. Logic helps understand the meaning and context of mathematics and convey mathematical ideas clearly and consistently to others (Anthony & Walshaw, 2009). In a cultural context, human thinking logic is crucial for ensuring correct understanding and effective communication about mathematical concepts (Fouze & Amit, 2018). For instance, logic helps correctly interpret statistical data and describe statistical analysis results so others can easily understand them. Thus, human thinking logic has a significant influence on the development and enhancement of understanding of mathematical concepts, helping to understand the patterns, relationships, and structures underlying them.

3.1.2. Application of Mathematical Concepts

Mathematics has existed since ancient times and become an integral part of human life (Ernest et al., 2016). Concepts like numbers, counting, patterns, and relationships between objects and natural phenomena have been widely used in various aspects of human life and culture. One main benefit of using concepts identical to mathematics is related to planning. Mathematics helps humans plan daily activities, such as scheduling, calculating food needs, or planning financial budgets (Gibert et al., 2024). Utilizing mathematical concepts helps create more effective and efficient plans to achieve set goals. Furthermore, mathematical concepts are also used for measurement. Humans use mathematics to measure various objects or phenomena. For instance, in architecture, mathematics measures building dimensions and plans room layouts. In other sciences, mathematics measures distances between planets, calculates object speed, or measures temperature. Using mathematics in measurement helps humans accurately understand and describe the world around them (Burrough et al., 2015).

Resource management is also greatly aided by mathematical concepts (Stern, 2003). Humans often face complex resource management problems. Using mathematical concepts, humans can develop mathematical models that help manage resources efficiently (Brauer et al., 2019). For example, in managing water usage, mathematics predicts rainfall patterns, optimizes water use, or calculates agricultural water needs. Mathematics helps humans make more targeted decisions in managing limited resources.

Solving complex problems is also a crucial part of using mathematical concepts in community life and culture (Saraswati et al., 2025). Complex problems typically involve various variables and intricate relationships. Here, mathematics provides tools and methods to help analyze and solve these problems. For instance, in technology, mathematics helps develop algorithm systems and mathematical models that enable humans to solve complex problems like route optimization, demand forecasting, or other data analysis. With mathematical concepts, humans can find solutions to complex problems in a more structured, effective, and efficient manner. Overall, mathematical concepts within a culture highly significantly influence planning, measurement, resource management, and complex problem-

solving (Verschaffel et al., 2020). Mathematics helps humans make better decisions, understand environmental phenomena more accurately, and solve complex problems more structurally.

3.1.3. Interpretation and Communication

Human thinking logic plays an important role in ensuring accurate interpretation and effective communication of mathematical concepts within a culture (Anthony & Walshaw, 2009). Thinking logic is a human ability to use reasoning and rational argumentation in applying mathematical concepts. This involves combining logical rules and principles to solve problems using mathematical concepts and convey mathematical ideas clearly and structured. Human thinking logic is the foundation for building a strong understanding of mathematics in culture (Lakoff & Núñez, 1997). In learning mathematics, one must develop the ability to think logically and rationally, requiring the ability to identify patterns and construct coherent arguments. Conveying mathematical ideas also requires thinking logic to provide clear and structured information. Effective communication about mathematics requires precise language and organizing mathematical ideas logically (O'Halloran, 2015). Thinking logic helps humans construct coherent arguments and avoid misunderstandings in mathematical communication.

Humans are often faced with mathematical problems requiring systematic and logical solutions. Thinking logic helps identify patterns, develop problem-solving strategies, and outline logical steps to find the right solution (Steffensen, 2013). Without thinking logic, humans would struggle to solve complex mathematical problems. Furthermore, human thinking logic impacts the development of dynamic cultures. In culture, using logic in mathematics supports the development of technology, science, and art (Oanh & Dang, 2025). Logic enables humans to perform accurate calculations, conduct systematic research, and create aesthetic works of art.

In culture, using logic in mathematics helps develop a deeper understanding of the world and enhances human capacity for critical and creative thinking (Baharin et al., 2018). Overall, human thinking logic has a crucial role in culture, ensuring accurate understanding and effective communication of mathematical concepts. Using logic in mathematics has significant impacts on various aspects of human life. Logic assists in developing, applying, interpreting, and communicating mathematical concepts rationally and consistently (Siregar, 2025). Moreover, using mathematical concepts based on human thinking logic provides benefits for various aspects of cultural life, including education, technology, economics, and complex problem-solving (Pickering et al., 2025).

The findings demonstrates that human logical thinking plays a fundamental role in the development, application, interpretation, and communication of mathematical concepts. Logical reasoning enables individuals to recognize patterns and relationships, apply mathematical knowledge to planning, measurement, resource management, and problem solving, and communicate mathematical ideas in a clear and structured manner. Importantly, these processes are embedded within cultural contexts, showing that mathematical thinking is not limited to formal academic settings but develops through and contributes to everyday cultural practices. Thus, the interaction between logical thinking, mathematics, and culture strengthens both practical problem-solving abilities and the broader development of human knowledge.

3.2. *Aspects of Human Thinking Logic Relevant to the Ethnomathematics Context*

In the ethnomathematics context, several aspects of human thinking logic are relevant, as illustrated in the following chart (figure 2). It states that thinking logic within the ethnomathematical context can be understood through three interrelated aspects: patterns and relationships, systems and structures, and problem solving. Ethnomathematics provides the broader cultural context in which logical thinking emerges and is applied. Patterns and relationships involve the recognition of regularities, sequences, symmetry, and connections embedded in cultural practices. Systems and structures refer to the logical organization of cultural knowledge, practices, and relationships, while problem solving reflects the application of logical and mathematical reasoning to address practical challenges within a particular cultural environment. Together, these three aspects demonstrate how logical thinking connects culturally embedded knowledge and practices with mathematical ideas and reasoning.

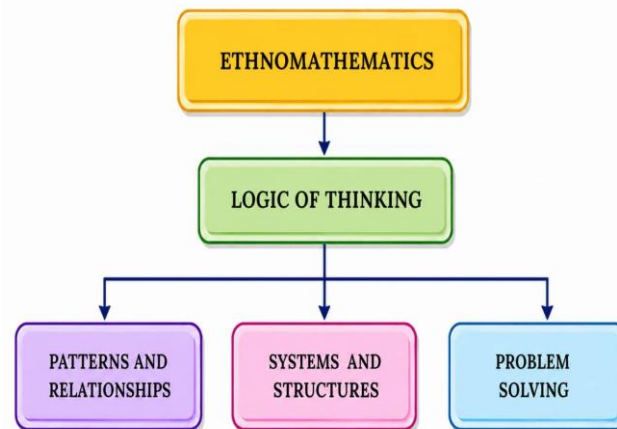


Figure 2. Aspects of thinking logic in the ethnomathematics context.

3.2.1. Patterns and Relationships

In ethnomathematics, human thinking logic plays a crucial role in developing the ability to recognize patterns and relationships between mathematical elements within a specific culture. Thinking logic is the human ability to use rational thought and argumentation to understand and analyze information. A pattern is a repeated sequence or arrangement of elements from a set. In mathematics, patterns occur in various objects, such as number patterns, geometric patterns, or symmetry patterns (Muhtadi et al., 2017). In ethnomathematics, humans use logic to recognize these patterns in traditional mathematical practices within a developing culture (Marsigit et al., 2026). For example, in a traditional art, patterns appear in designs or motifs of clothing, buildings, or other arts developed and used since ancient times. Thinking logic helps identify these patterns, understand their underlying principles, and connect them to mathematical concepts.

Patterns and relationships constitute the foundational aspect of mathematical thinking. Human beings naturally recognize repetitions, symmetries, sequences, and proportional relations in their environment. In the context of Batak Mandailing and Batak Toba cultures, such patterns are prominently represented in traditional ornaments, *ulos* motifs, rhythmic musical structures, and ceremonial arrangements (Ascher & D'Ambrosio, 1994). The repeated geometrical motifs found in *ulos* weaving demonstrate sophisticated understandings of transformation geometry, tessellation, symmetry, and arithmetic sequences (Ramadhani et al., 2024).

From a cognitive perspective, recognizing patterns reflects the human ability to generalize experiences and construct abstract reasoning. This process represents the earliest form of mathematical logic because individuals begin to identify predictable relationships among objects and events. Consequently, cultural artifacts become media through which mathematical abstraction is developed and transmitted across generations (Ramadhani et al., 2024).

Besides patterns, human thinking logic also involves identifying relationships between mathematical elements in a specific culture. A relationship is a connection between two or more elements. In mathematics, relationships can be between numbers, geometric shapes, or other mathematical concepts (Vergnaud, 1997). In ethnomathematics, humans use logic to understand these relationships, especially in traditional mathematical practices (Payadnya et al., 2024). For instance, a traditional calendar system shows relationships between years, months, and days. Thinking logic helps recognize these relationships, understand emerging patterns within them, and connect them to mathematical concepts.

Human thinking logic in recognizing patterns and relationships in ethnomathematics also requires the ability to make logical inferences (Katsap & Silverman, 2016). Logical inference uses available information to draw rational conclusions. In ethnomathematics, humans use logic to make inferences about mathematical patterns and relationships in their culture (Payadnya et al., 2024). For instance, seeing a repeating pattern in traditional art, one can infer that the pattern has specific mathematical meaning. Thinking logic also helps make inferences about relationships between mathematical concepts in that culture. For example, seeing a relationship between size and shape in traditional architecture, one can infer a mathematical relationship between the two concepts.

Furthermore, human thinking logic in ethnomathematics involves understanding systems and mathematical structures within a specific culture. A system is a set of rules and principles governing the use of mathematics in daily life (Zaenuri et al., 2023). In ethnomathematics, humans use logic to understand the measurement system, numbering system, or calculation system used in their culture (Sugiman et al., 2025). Thinking logic helps understand the rules and principles underlying these mathematical systems and structures (Siregar, 2024). For example, in a traditional measurement system, humans use logic to understand conversions between different measurement units or recognize relationships between them.

3.2.2. Systems and Structures

The second component, systems and structures, reflects the human tendency to organize knowledge, space, and social life systematically. Mathematics fundamentally relies on structures, classifications, hierarchies, and relational systems. Similarly, traditional societies construct cultural systems governed by logical order and proportional balance (Umbara et al., 2025). In Batak Toba culture, the architecture of the Rumah Bolon illustrates mathematical principles related to geometry, measurement, balance, and structural proportionality. Likewise, the Bagas Godang in Mandailing culture demonstrates carefully designed spatial organization reflecting social hierarchy, communal interaction, and environmental adaptation. These structures reveal that indigenous communities employ logical and mathematical reasoning in practical contexts long before the introduction of formal modern mathematics. The relationship between mathematical structures and cultural systems also appears in kinship arrangements such as Dalihan Na Tolu in Batak society. This philosophical system organizes social interaction through balanced relational roles, indirectly reflecting logical classification and systemic reasoning (Ramadhani et al., 2024). Therefore, systems and structures within ethnomathematics are not limited to physical objects but also encompass social and philosophical organization.

In ethnomathematics, human thinking logic plays an important role in building an understanding of mathematical systems and structures within a specific culture (Sunzuma & Umbara, 2025). Humans use logic to understand how mathematical concepts are organized and interrelate in that culture. This requires understanding the rules and principles governing mathematics use in daily life, such as measurement, numbering, or calculation systems. A mathematical system is a collection of concepts, rules, and principles forming the basis of mathematics in a culture. Each culture has a unique mathematical system reflecting its worldview and needs. Human thinking logic helps understand these systems by observing patterns and relationships between mathematical concepts within the culture. One example is the measurement system (Siregar, 2025). Each culture has its own way of measuring things like length, mass, or time. For example, Western culture uses the metric system, while other cultures, like traditional tribes, use different units such as *jengkal* (hand span) or *batang* (stick). Thinking logic helps understand the rules and principles behind these measurement systems, enabling correct usage and understanding of related mathematical concepts (dos Santos Bernardi & Santos, 2021).

Additionally, human thinking logic plays a role in understanding numbering systems. Each culture uniquely represents numbers and performs mathematical operations (Duval, 2017). For instance, Arabic culture uses the decimal system, but other cultures use different systems like Roman or binary. Thinking logic helps understand the structure of these numbering systems and how to perform operations correctly (Zaenuri et al., 2023). Besides measurement and numbering systems, human thinking logic is relevant for understanding calculation systems in specific cultures. Each culture has its own way of performing mathematical calculations like addition, subtraction, multiplication, and division (Zuliana et al., 2023). Thinking logic helps understand the rules and principles governing these calculation systems. For example, in Western culture, we use the Arabic numeral system and related calculation rules. However, other cultures, like traditional African tribes, might use different systems like finger calculation or pattern-based calculation. Human thinking logic helps understand these methods and use the calculation system correctly (Hsu et al., 2018).

3.2.3. Problem Solving

In the mathematical context, human thinking logic plays a key role in identifying problems solvable with mathematical concepts, developing problem-solving strategies, and outlining logical steps to find the right solution. Thinking logic requires critical thinking, information analysis, and making rational inferences within the cultural mathematical context.

First, human thinking logic can be used to identify problems in mathematics (Bahadir, 2021). When faced with situations involving mathematical concepts, humans use logic to recognize a problem or phenomenon requiring a mathematical solution (English & Gainsburg, 2015). For example, in daily life, someone needs a way to calculate the amount of money they have, or in another case, geometry concepts are needed when designing a building. In identifying problems connected to mathematical concepts, logic helps humans determine situations needing a solution (Zuliana et al., 2023).

After identifying the mathematical problem, human thinking logic develops problem-solving strategies. Humans use logic to determine various potential ways to solve the mathematical problem. Using previously learned mathematical knowledge, they can consider different approaches or try applying relevant mathematical principles (Hatano, 1996). Mathematical modeling, calculation, or manipulation of mathematical symbols can also be used to aid problem-solving. Thinking logic helps ensure that the steps taken in solving mathematical problems are consistent, accurate, and reliable (Hendrycks et al., 2021).

When working with mathematical concepts related to a specific cultural context, humans use logic to critically consider the information received. Thinking logic helps correctly understand and interpret mathematical concepts within that cultural context. Furthermore, human thinking logic is important for avoiding errors and misunderstandings in mathematical problem-solving (Schoenfeld, 1994). Humans use logic to identify and avoid logical fallacies that might occur. They need to check solution steps, ensure arguments are consistent, and pay attention to important details in problem-solving. Thinking logic helps ensure the chosen mathematical solution is valid and justifiable (Hendriyanto et al., 2023; Bahadir, 2021). Overall, human thinking logic is an essential skill in the mathematical context. In identifying mathematical problems, developing solution strategies, outlining logical steps, thinking critically, analyzing information, and making rational inferences, human thinking logic plays a central role.

It was indicated that logical thinking in ethnomathematics is manifested through three closely connected aspects: patterns and relationships, systems and structures, and problem solving. These aspects show how culturally embedded practices involve the recognition of mathematical regularities, the organization of knowledge into coherent systems, and the application of reasoning to practical problems. In the Batak Mandailing and Batak Toba contexts, such thinking is reflected in cultural artifacts, architectural forms, social systems, measurement practices, and everyday activities. Thus, ethnomathematics demonstrates that logical and mathematical thinking develops not only through formal education but also through culturally situated knowledge and practices transmitted across generations.

3.3. Description and Conceptual Elaboration of the Integrated Logic-of-Thinking Scheme in Ethnomathematics

Figure 3 illustrates a comprehensive conceptual relationship between human logical thinking, mathematical concepts, and ethnomathematics within cultural contexts. The diagram does not merely represent a linear relationship among concepts, but rather portrays an interconnected epistemological framework explaining how mathematics emerges, develops, and functions through human cognitive activity embedded in culture (Sunzuma & Umbara, 2025). In this perspective, mathematics is understood not only as a formal and abstract discipline, but also as a cultural product constructed through human interaction, reasoning, and social experience.

At the highest conceptual level, the scheme positions ethnomathematics as the cultural domain in which mathematical ideas are produced, interpreted, and practiced. Ethnomathematics emphasizes that mathematical knowledge is inseparable from the traditions, values, symbols, artifacts, and daily activities of a particular society. Mathematical reasoning therefore evolves through cultural practices such as architecture, weaving, traditional measurements, spatial organization, economic exchange, and ritual systems. Within Batak Mandailing and Batak Toba societies, ethnomathematics can be observed in the geometrical motifs of *ulos* weaving, the proportional structure of traditional houses, kinship arrangements, and ceremonial patterns that reflect implicit mathematical reasoning (Hendriyanto et al., 2023).

The framework positions ethnomathematics as a cultural domain in which mathematical knowledge is created, interpreted, and applied through human interaction within society (Sunzuma & Umbara, 2025). In this perspective, mathematics is not merely regarded as an abstract and universal discipline detached from social life, but rather as a form of knowledge deeply rooted in cultural experiences and collective human activities. Ethnomathematics

highlights that mathematical concepts emerge naturally from the ways communities organize their environments, solve practical problems, and preserve cultural traditions across generations (Ramadhani et al., 2022).

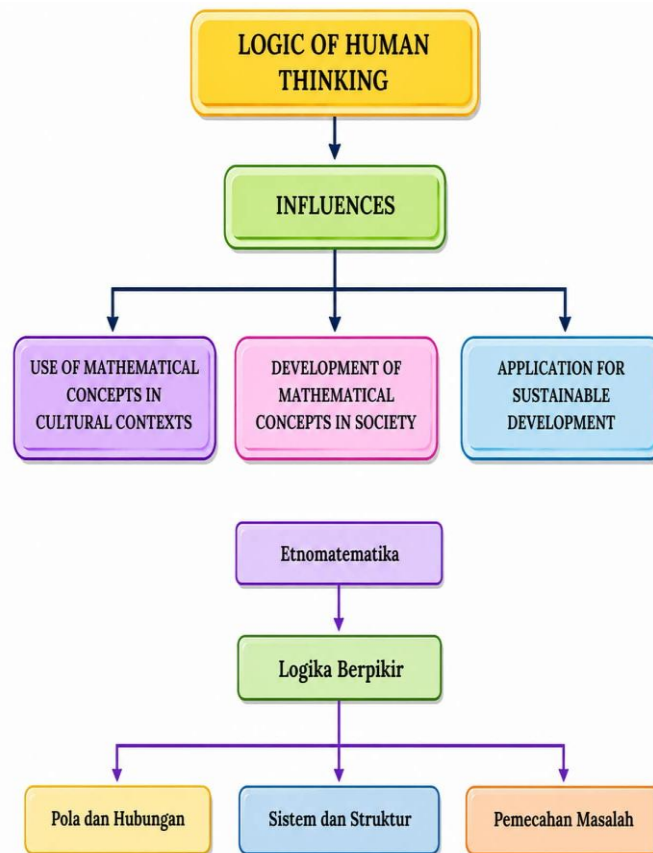


Figure 3. Conceptual elaboration of the integrated logic-of-thinking scheme in ethnomathematics.

Consequently, mathematical reasoning develops alongside the historical, philosophical, and social evolution of a particular society (Fernández-Oliveras et al., 2021). Cultural activities such as counting systems, spatial arrangements, architecture, trade, agriculture, and artistic production all contain implicit mathematical structures that reflect logical thinking processes. Through ethnomathematics, mathematics becomes more contextualized and meaningful because it is connected to the lived experiences of individuals and communities (Bahadir, 2021). This perspective challenges the dominance of purely formal mathematics by emphasizing that diverse cultures possess their own mathematical practices and intellectual contributions (Marwanto & Satriyono, 2021). Therefore, ethnomathematics serves as an interdisciplinary bridge connecting mathematics with anthropology, sociology, philosophy, and cultural studies. The framework ultimately demonstrates that mathematical knowledge is inseparable from human civilization and cultural identity.

Ethnomathematics further emphasizes that mathematical understanding is embedded within traditions, values, symbols, artifacts, and daily practices of a community. Mathematical ideas are often transmitted informally through social interaction, observation, and participation in cultural activities rather than exclusively through formal education (dos Santos Bernardi & Santos, 2021). Every cultural artifact, whether in the form of woven fabrics, traditional ornaments, ritual arrangements, or architectural structures, may contain mathematical principles related to symmetry, proportion, measurement, transformation, and pattern recognition. These principles reflect the logical thinking abilities of communities as they seek order, balance, and harmony within their environment (Ramadhani et al., 2022). The cultural transmission of mathematical knowledge also demonstrates that mathematics is dynamic and adaptive, evolving according to the needs and worldview of a society.

In many indigenous communities, mathematical reasoning is integrated into practical life, making it functional, contextual, and closely connected to local wisdom (Fernández-

Oliveras et al., 2021). Ethnomathematics therefore recognizes the intellectual richness of traditional societies whose mathematical contributions are often overlooked in conventional educational discourse (Marwanto & Satriyono, 2021). By exploring mathematical ideas embedded in culture, researchers can uncover alternative forms of reasoning and problem-solving strategies that enrich global mathematical understanding (Bahadir, 2021). This perspective also encourages culturally responsive education by integrating local knowledge into mathematics learning processes. As a result, students can develop stronger connections between mathematical concepts and their own cultural identities.

Within Batak Mandailing and Batak Toba societies, ethnomathematics can be clearly identified through various cultural expressions that embody implicit mathematical reasoning. One of the most prominent examples is the geometrical motifs found in *ulos* weaving and Mandailing woven fabrics, which display repetitive patterns, symmetry, transformations, and proportional relationships (Ramadhani et al., 2022). These motifs are carefully arranged to create aesthetic harmony while simultaneously conveying philosophical meanings related to balance, unity, and continuity of life (Fernández-Oliveras et al., 2021). Mathematical concepts are also reflected in the proportional structure of traditional houses such as Rumah Bolon and Bagas Godang, where measurements, spatial organization, and structural balance are systematically applied to ensure functionality and stability. In addition, kinship systems and ceremonial arrangements within Batak culture reveal logical classifications, hierarchical structures, and organized relational patterns that demonstrate systemic reasoning (Fernández-Oliveras et al., 2021). Traditional ceremonies often involve calculations related to participant organization, distribution of resources, and symbolic spatial positioning, all of which require mathematical thinking and logical decision-making. These cultural practices illustrate that mathematical reasoning exists not only in formal academic settings but also in everyday social and cultural activities (Bahadir, 2021). The ethnomathematical practices of Batak Mandailing and Batak Toba communities therefore provide valuable evidence that mathematics is deeply interconnected with cultural identity and human cognition. Through this perspective, mathematics can be understood as a living cultural practice that evolves through collective experience and social interaction (Marwanto & Satriyono, 2021).

The second layer of the scheme introduces Logic of Thinking as the central cognitive mechanism connecting culture and mathematics (Mania & Alam, 2021). Human logical thinking functions as an intellectual process enabling individuals and communities to identify regularities, establish relationships, formulate structures, and solve contextual problems (Ramadhani et al., 2024). In ethnomathematical studies, logical thinking becomes the bridge through which cultural experiences are transformed into mathematical understanding. The scheme therefore highlights that mathematical concepts do not emerge in isolation; rather, they are rooted in collective reasoning processes shaped by social interaction and cultural adaptation.

The second layer of the framework introduces the concept of the Logic of Thinking as the primary cognitive mechanism that connects culture and mathematics within ethnomathematical studies. Logical thinking functions as an intellectual process that enables individuals and communities to recognize regularities, establish meaningful relationships, formulate organized structures, and solve contextual problems encountered in daily life. In this perspective, mathematical reasoning is not viewed as an isolated mental activity but as a cognitive process shaped through interaction with cultural environments and social experiences. Human beings continuously use logic to interpret patterns, organize information, and make decisions in ways that are relevant to their cultural realities (Nur et al., 2021).

Consequently, logical thinking becomes the foundation through which cultural practices are transformed into mathematical understanding and knowledge systems. Through observation, repetition, comparison, and abstraction, communities gradually develop mathematical ideas that later become integrated into traditions and social activities (Fouze & Amit, 2018). This process demonstrates that mathematical cognition evolves naturally through human interaction with the surrounding environment (Mania & Alam, 2021). Ethnomathematics therefore emphasizes that culture plays a crucial role in shaping how individuals perceive and apply mathematical concepts. The framework highlights that logic is not merely a formal reasoning tool but also a culturally influenced cognitive activity that develops within specific social contexts (Ramadhani et al., 2024).

Furthermore, the logic of thinking allows communities to organize cultural practices systematically and meaningfully, thereby creating implicit mathematical structures within traditional life. In many indigenous societies, mathematical concepts emerge from practical activities such as weaving, architecture, trade, agriculture, navigation, and ceremonial

organization (Ramadhani et al., 2024). These activities require individuals to employ logical reasoning related to measurement, estimation, classification, sequencing, and spatial organization.

Through continuous participation in such cultural activities, communities develop collective reasoning patterns that form the basis of ethnomathematical knowledge. Within Batak Mandailing and Batak Toba societies, for example, logical thinking can be observed in the arrangement of *ulos* motifs, the proportional structure of traditional houses, and the systematic organization of customary ceremonies (Patri & Heswari, 2021). These practices demonstrate that cultural activities contain sophisticated mathematical reasoning even though they may not be formally expressed through modern mathematical notation. The logic of thinking therefore acts as a bridge connecting practical experiences with abstract mathematical concepts. This relationship also illustrates that mathematical understanding is socially constructed through interaction, communication, and cultural adaptation (Mania & Alam, 2021). As individuals engage in cultural traditions, they simultaneously develop cognitive abilities related to pattern recognition, structural analysis, and problem-solving. As a result, mathematical logic becomes deeply embedded within cultural identity and communal knowledge systems.

The framework further emphasizes that mathematical concepts do not emerge independently or universally detached from human experience, but rather evolve through collective reasoning processes influenced by social interaction and cultural adaptation (Nur et al., 2021). Every society develops unique ways of understanding quantity, space, measurement, and relationships according to its environmental conditions and cultural needs. This indicates that mathematical knowledge is dynamic and contextually shaped rather than completely fixed and culturally neutral (Patri & Heswari, 2021). Logical thinking enables communities to adapt mathematical reasoning to solve real-life problems while preserving cultural values and traditions. In ethnomathematical studies, this perspective challenges the conventional assumption that mathematics exists solely within formal academic institutions.

Instead, it recognizes that local communities possess valuable mathematical knowledge developed through centuries of practical experience and cultural transmission (Umbara et al., 2023). The integration of logic, culture, and mathematics therefore creates a holistic understanding of human cognition and intellectual development. Through collective reasoning, communities construct systems of knowledge that support social organization, economic activities, artistic production, and cultural continuity. This process demonstrates that mathematics is fundamentally a human activity closely related to cultural evolution and social interaction. Ultimately, the second layer of the framework illustrates that logical thinking serves as the essential cognitive bridge through which culture and mathematics continuously influence and enrich one another.

The lower section of the scheme further elaborates the operational dimensions of logical thinking through three interconnected components: patterns and relationships, systems and structures, and problem solving. These components collectively explain how mathematical cognition develops within cultural practices. These three components collectively illustrate how mathematical cognition develops naturally within cultural activities and everyday human experiences. The framework emphasizes that logical thinking is not limited to abstract reasoning in formal educational settings, but also emerges through continuous interaction with cultural practices, social organization, and environmental adaptation (Umbara et al., 2023). Each component represents a fundamental cognitive ability that allows individuals and communities to understand, organize, and respond to the complexities of life systematically. Through these dimensions, mathematics becomes closely connected to practical activities such as weaving, architecture, trade, agriculture, and ritual organization. The interconnectedness among the three components demonstrates that mathematical understanding evolves holistically rather than independently. Individuals first recognize patterns and relationships, then organize them into systems and structures, and finally apply them in solving contextual problems. This process reflects the natural progression of human cognition in constructing mathematical meaning from real-life situations. And the framework positions ethnomathematics as an important approach for understanding the relationship between culture, cognition, and mathematical development.

The first component, patterns and relationships, highlights the human ability to identify regularities, repetitions, symmetries, and connections among objects or events within cultural environments. This cognitive skill represents one of the earliest foundations of mathematical reasoning because humans naturally seek order and predictability in their surroundings. In ethnomathematical contexts, patterns can be observed in traditional ornaments, weaving

motifs, rhythmic musical arrangements, architectural decorations, and ceremonial sequences. These patterns often reflect sophisticated understandings of geometry, arithmetic progression, symmetry, and transformation even though they are expressed through cultural artifacts rather than formal mathematical symbols (Orey & Rosa, 2021). The recognition of relationships among shapes, numbers, and spatial arrangements enables communities to preserve aesthetic harmony and functional balance in their cultural products. Within Batak Mandailing and Batak Toba cultures, repetitive motifs found in *ulos* weaving and *gora* carvings demonstrate the practical application of mathematical relationships in artistic traditions (Umbara et al., 2023). This ability to identify and organize patterns shows that mathematical cognition develops through observation, experience, and social participation. As individuals engage with cultural practices, they unconsciously internalize mathematical concepts embedded in their environment. Therefore, patterns and relationships serve as the cognitive foundation linking logical thinking with cultural expression and mathematical understanding.

The second and third components, systems and structures as well as problem solving, further demonstrate how logical thinking operates within cultural contexts to support organization and practical decision-making. Systems and structures refer to the human capacity to organize information, space, social interaction, and cultural activities systematically according to logical principles (Ascher & D'Ambrosio, 1994). This dimension is reflected in traditional architectural designs, kinship systems, spatial organization, and ceremonial arrangements that require balance, proportion, hierarchy, and structural consistency. In Batak culture, for instance, the organization of Rumah Bolon and Bagas Godang reflects mathematical reasoning related to geometry, measurement, and proportionality.

Meanwhile, problem solving represents the practical application of logical thinking to address contextual challenges encountered in everyday life. Communities use mathematical reasoning to determine quantities, distribute resources, organize ceremonies, estimate production, and optimize work processes efficiently (Mania & Alam, 2021). Traditional craftsmen, for example, apply logical strategies when arranging weaving motifs without counting every detail individually. This demonstrates higher-order thinking skills involving analysis, estimation, and strategic reasoning (Ascher & D'Ambrosio, 1994). Together, systems and structures provide the organizational foundation, while problem solving enables the practical implementation of mathematical logic within cultural life.

The interaction among these three components ultimately illustrates that mathematics develops not only as an academic discipline but also as a living cognitive and cultural practice deeply rooted in human civilization. Problem solving represents the practical manifestation of logical thinking in everyday life. Human beings continuously encounter challenges requiring reasoning, estimation, optimization, and decision-making. Mathematics becomes an essential cognitive tool for addressing such challenges efficiently. Within Batak Mandailing and Batak Toba communities, mathematical problem solving can be observed in agricultural planning, land division, traditional trade systems, ceremonial budgeting, and weaving production. For example, determining the number of motifs in *ulos* weaving requires counting strategies, proportional reasoning, and spatial visualization. Similarly, organizing traditional ceremonies involves systematic calculations related to resource allocation, participant arrangement, and ritual sequencing (Ramadhani et al., 2024). From the ethnomathematical perspective, problem solving demonstrates that mathematics is inherently contextual and functional. Mathematical logic develops because communities need practical solutions to sustain social and cultural life. Consequently, culture serves not only as the context of mathematics but also as a source of mathematical innovation.

The integration of the two schemes demonstrates a multidimensional relationship between ethnomathematics and human logical thinking. The upper scheme emphasizes the broader influence of logical thinking on the development and application of mathematical concepts in society, whereas the lower scheme operationalizes how logical thinking functions cognitively through patterns, systems, and problem solving. Together, these schemes reveal that ethnomathematics is simultaneously cognitive, cultural, and social. Human logical thinking enables individuals to interpret cultural experiences mathematically, while cultural practices provide concrete contexts for the emergence of mathematical concepts (Bardin, 2018). The interaction between logic, culture, and mathematics therefore forms a dynamic cycle in which cultural activities stimulate reasoning, reasoning produces mathematical abstraction, and mathematical abstraction subsequently reinforces cultural organization and sustainability (Ramadhani et al., 2024).

This integrated perspective is particularly relevant in contemporary mathematics education because it challenges the dominance of purely formal and decontextualized

instruction (Yanti, 2025). By incorporating ethnomathematical elements from Batak Mandailing and Batak Toba cultures, mathematics learning becomes more meaningful, contextualized, and culturally responsive. Students are encouraged not only to master formulas and procedures but also to understand mathematics as a living human activity deeply connected to identity, heritage, and social reality (Cabrera et al., 2024).

The integrated scheme affirms that mathematical thinking is fundamentally a manifestation of human logical reasoning shaped by cultural experience. Ethnomathematics therefore provides an important framework for understanding mathematics as both a scientific discipline and a cultural expression of human civilization (Solares-Rojas et al., 2026). The integration of the two schemes demonstrates that human logical thinking serves as the central foundation for understanding, developing, and applying mathematical concepts, both in general contexts and within cultural contexts (ethnomathematics) (Yanti, 2025). The first scheme emphasizes that human logical thinking influences the use of mathematical concepts in culture, the development of mathematical concepts in society, and their application for the sustainability of human life. Meanwhile, the second scheme illustrates that, within ethnomathematics, logical thinking is manifested through three major abilities, particularly recognizing patterns and relationships, understanding systems and structures, and applying problem-solving strategies (Orey & Rosa, 2021).

Further it is worth analysing these schemes in details. Firstly, patterns and relationships refer to the ability to recognize regularities, symmetries, repeated motifs, and relationships among cultural elements (Yanti, 2025). In Batak Mandailing and Batak Toba cultures, these patterns can be observed in *ulos* ornaments, *gorga* carvings, traditional house designs, and the rhythmic arrangements of traditional musical instruments. Such patterns reflect mathematical concepts related to geometry, transformation, and numerical sequences. Secondly, systems and structures explain how communities construct rules, spatial arrangements, and social structures logically and systematically (Solares-Rojas et al., 2026). Examples can be found in the structure of the Batak Toba Rumah Bolon and the Mandailing Bagas Godang, which are built based on proportion, balance, and constructional strength. These structures embody mathematical concepts such as ratio, symmetry, measurement, and geometric forms. And thirdly, problem solving is associated with the community's ability to utilize mathematical logic in solving everyday life problems, such as the distribution of harvest yields, determining traditional ceremonial schedules, weaving pattern arrangements, and spatial organization during customary ceremonies. This demonstrates that mathematics functions as a practical thinking tool deeply integrated with culture. And logical thinking acts as a bridge connecting formal mathematical concepts with local cultural practices.



Figure 4. Examples of Batak Toba Ulos and Mandailing woven fabrics with repetitive geometric patterns in the form of triangles and rhombuses on the cloth (Ulos Batak).

Source: Department of Culture and Tourism of North Sumatra Province, Indonesia, 2026.

Figure 4 presents several examples of traditional Batak Toba Ulos and Mandailing woven

fabrics, illustrating the prominent use of repetitive geometric patterns, particularly triangles and rhombuses. These motifs are arranged systematically in horizontal and vertical bands and display variations in size, color, orientation, and spatial configuration. Despite differences among the individual fabrics, the designs demonstrate clear principles of repetition, symmetry, sequencing, and geometric transformation. The recurring triangular and rhombic forms reveal how mathematical concepts are embedded in traditional textile-making practices and provide concrete examples of ethnomathematical knowledge expressed through cultural artifacts. From an educational perspective, these patterns can be used to support the development of logical and mathematical thinking by encouraging learners to identify regularities, classify geometric forms, analyze symmetry, predict pattern sequences, and examine relationships among repeated elements. At the same time, Appendix A shows example of a higher-order thinking skills (HOTS) problem based on Batak Mandailing and Batak Toba ethnomathematics.

This problem reflects the interconnected elements of patterns and relationships, systems and structures, and problem solving within the ethnomathematical framework. The incremental arrangement of motifs demonstrates the community's ability to recognize regularities and numerical relationships embedded in Batak weaving practices. At the same time, the systematic organization of the motifs maintains symmetry and aesthetic balance in the fabric, reflecting the structured nature of traditional Batak cultural practices. Mathematical logic is also evident in the way craftspeople determine the number and arrangement of motifs efficiently without counting each element individually. Thus, the weaving process illustrates how pattern recognition, structural reasoning, and practical problem-solving operate together as forms of logical thinking within a culturally situated mathematical practice.

4. Discussion

This study aims to explore the relationship between human logical thinking and the development of mathematical concepts within cultural contexts, specifically in Batak Mandailing and Batak Toba ethnomathematics. The findings of this literature review reveal three main aspects that serve as the foundation for understanding this relationship: (1) patterns and relationships, (2) systems and structures, and (3) problem solving. These three aspects collectively demonstrate how mathematical reasoning is embedded in cultural practices and how logical thinking functions as a cognitive bridge connecting culture with mathematical abstraction.

The findings indicate that the ability to recognize patterns and relationships is the most fundamental aspect of logical thinking in ethnomathematics. In Batak Mandailing and Batak Toba cultures, this is evident in the repetitive geometric motifs of *ulos* weaving, which demonstrate arithmetic sequences, symmetry, and transformation geometry (Siregar, 2025; Ramadhani et al., 2024). This finding aligns with D'Ambrosio (2018) who asserted that mathematical ideas emerge naturally from human activities and cultural traditions. The recognition of patterns reflects what Cellucci (2013) describes as the basic human capacity to identify regularities and construct systematic reasoning from environmental observations.

This finding suggests that mathematical thinking does not require formal education to emerge; rather, it develops through cultural participation and intergenerational knowledge transmission. Traditional craftsmen in Batak communities unconsciously apply mathematical concepts when arranging *ulos* motifs, demonstrating that logical reasoning is inherently embedded in cultural production. This challenges the conventional view that mathematics is exclusively a formal academic discipline and supports the perspective that mathematical cognition evolves through social interaction and cultural adaptation (Orey & Rosa, 2021; Umbara et al., 2023).

However, what distinguishes this finding from previous studies is the explicit connection between pattern recognition in weaving traditions and the broader logical thinking processes of the Batak people. While recent research (Baker, 2022; Zhang & Zhang, 2010) discussed ethnomathematics in general cultural contexts, this study specifically demonstrates how repetitive patterns in *ulos* weaving reflect higher-order thinking skills such as generalization, prediction, and abstraction. This indicates that Batak traditional craftsmen possess sophisticated cognitive abilities comparable to formal mathematical reasoning, though expressed through cultural artifacts rather than mathematical symbols.

The second finding reveals that systems and structures in Batak culture reflect the systematic organization of mathematical logic. This is observed in the proportional architecture of Rumah Bolon and Bagas Godang, which applies principles of geometry,

measurement, and structural balance (Sunzuma & Umbara, 2025; Orey & Rosa, 2021). Additionally, kinship systems such as Dalihaan Na Tolu demonstrate logical classification and hierarchical organization that mirror mathematical structures (Ramadhani et al., 2024).

This finding corroborates the work of Vergnaud (1997) who argues that mathematical systems are cultural constructs reflecting a society's worldview and practical needs. The architectural precision of Batak traditional houses reveals that indigenous communities employ logical and mathematical reasoning in practical contexts long before formal mathematics was introduced. This supports D'Ambrosio (2018) and claims that mathematics is a human creation shaped by cultural and historical contexts. From the researcher's perspective, the integration of systems and structures in Batak culture demonstrates that mathematical logic is not limited to numerical operations but extends to spatial organization, social relationships, and philosophical values. The symmetrical arrangement of traditional houses and the balanced roles within kinship systems reflect a cultural commitment to harmony, order, and proportionality. This indicates that mathematical thinking in Batak culture is inherently connected to ethical and social values, a dimension often overlooked in formal mathematics education. What is particularly significant in this finding is the dual function of systems and structures: they serve both practical purposes (such as ensuring building stability and organizing social interactions) and symbolic purposes (such as representing cultural identity and philosophical beliefs). This dual function distinguishes Batak ethnomathematics from purely utilitarian mathematical applications and highlights the profound interconnection between mathematics and culture.

The third finding demonstrates that problem solving in Batak communities reflects the practical application of logical thinking in everyday life. Traditional activities such as agricultural planning, ceremonial budgeting, and weaving production require systematic calculations, estimation, resource allocation, and strategic decision-making (Ramadhani et al., 2024; Siregar, 2025). Craftsmen use logical reasoning to determine the number of motifs, arrange symmetrical patterns, and optimize work processes efficiently without counting each detail individually (Eglash et al., 2020). This finding aligns with certain works (English & Gainsburg, 2015; Schoenfeld, 1994) which emphasize that problem solving is a fundamental cognitive skill developed through practical engagement with real-world challenges. The ethnomathematical perspective extends this understanding by demonstrating that problem-solving strategies are culturally shaped and contextually embedded (Alangui, 2017; Bahadir, 2021). In Batak culture, problem solving is not an isolated academic exercise but an integrated aspect of cultural survival and sustainability. This information reveals that mathematical logic in Batak communities is inherently practical and functional. Mathematics emerges as a response to real-life needs, such as resource management, social organization, and cultural preservation. This challenges the assumption that mathematics is purely abstract and context-free and supports the argument that mathematical reasoning is fundamentally shaped by environmental and social conditions (Nur et al., 2021; Mania & Alam, 2021).

What distinguishes this study from previous research is the explicit identification of higher-order thinking skills in traditional problem-solving practices. The ability of Batak craftsmen to predict motif arrangements, estimate quantities, and maintain consistency in weaving demonstrates analytical, strategic, and creative thinking comparable to formal mathematical problem-solving. This suggests that indigenous knowledge systems contain sophisticated mathematical reasoning that deserves recognition and integration into educational practices (Yanti, 2025). The integration of the three aspects – patterns and relationships, systems and structures, and problem solving – demonstrates that logical thinking serves as the central cognitive mechanism connecting culture and mathematics.

The framework developed in this study illustrates that mathematical concepts do not emerge in isolation but evolve through collective reasoning processes shaped by social interaction and cultural adaptation (Ramadhani et al., 2024; Siregar, 2025). This integrated perspective aligns with D'Ambrosio's (2018) ethnomathematics program, which emphasizes that mathematics is a cultural product constructed through human activities, traditions, and logical reasoning. It also supports the work of Orey and Rosa (2021) as well as Sunzuma and Umbara (2025), who argue that ethnomathematics provides an important framework for understanding mathematics as both a scientific discipline and a cultural expression. And the integration of logic, culture, and mathematics in Batak traditions demonstrates that mathematical thinking is fundamentally a human activity embedded in social and cultural life. The Batak people do not separate mathematics from daily activities; rather, they integrate mathematical reasoning into weaving, architecture, ceremonial arrangements, and social organization. This holistic approach to mathematics challenges the fragmentation often found

in formal mathematics education and suggests the need for more contextualized, culturally responsive pedagogical approaches (Cabrera et al., 2024; Yanti, 2025).

When compared to previous studies, the findings of this research both confirm and extend existing knowledge in the field of ethnomathematics. Some studies (Baker, 2022; Zhang & Zhang, 2010; Anderson-Pence, 2013) have established that mathematics is culturally dependent and that mathematical concepts emerge from social practices. This study confirms these assertions by demonstrating that Batak Mandailing and Batak Toba cultures contain sophisticated mathematical reasoning in weaving, architecture, and kinship systems. However, this study extends previous research by explicitly focusing on human logical thinking as the cognitive mechanism connecting culture and mathematics. While earlier studies by D'Ambrosio (2018) and Alangui (2017) discussed ethnomathematics in general terms, this research provides a more detailed analysis of how logical thinking operates through patterns, systems, and problem solving within specific cultural contexts. This contributes to the theoretical development of ethnomathematics by offering a framework for understanding the cognitive processes underlying cultural mathematical practices.

The findings also challenge the dominance of purely formal and decontextualized mathematics education (Yanti, 2025; Mabotja, 2026). By demonstrating that indigenous communities possess sophisticated mathematical reasoning, this study supports the argument for integrating local knowledge into school curricula to make mathematics more meaningful, contextualized, and culturally responsive (Cabrera et al., 2024; Umbara et al., 2023). This has significant implications for mathematics education in multicultural societies, particularly in Indonesia where diverse cultural traditions coexist.

Despite its contributions, this study has several limitations. As a literature review, it relies on secondary sources and does not include primary data collection from Batak communities. Future research should employ ethnographic methods to directly observe and document mathematical practices in Batak Mandailing and Batak Toba societies, as suggested by D'Ambrosio (2018) and Umbara et al. (2025). Additionally, comparative studies across different Indonesian ethnic groups could provide broader insights into the diversity of ethnomathematical practices and their implications for mathematics education.

From the researcher's perspective, the findings of this study highlight the importance of preserving and documenting indigenous mathematical knowledge. As globalization and modernization threaten traditional cultural practices, there is an urgent need to record and integrate ethnomathematical knowledge into educational systems. This will not only enrich mathematical understanding but also contribute to cultural preservation and identity formation among younger generations (Siregar, 2025; Eglash, 2023).

The discussion confirms that human logical thinking strongly influences the application of mathematical concepts in Batak Mandailing and Batak Toba cultures through pattern recognition, systematic organization, and practical problem solving. The integration of these three aspects demonstrates that mathematics is not merely an abstract discipline but a living cultural practice deeply connected to human cognition, social organization, and philosophical values. This study contributes to the theoretical development of ethnomathematics by providing a framework for understanding the cognitive processes underlying cultural mathematical practices and by emphasizing the importance of integrating local knowledge into formal education.

5. Conclusions

Based on the research results, we have come to certain conclusions. Firstly, the relationship between human thinking logic and the development of mathematical concepts in society is mutually influential. Human thinking logic plays an important role in the development of mathematical concepts, as humans use their logic to formulate and understand mathematical concepts. Conversely, the development of mathematical concepts also influences human logic by training systematic and rational thinking processes. Secondly, human thinking logic influences the use of mathematical concepts in culture by enabling humans to understand and apply mathematical principles in daily life. It helps understand the relationships between numbers, patterns, and mathematical structures present in culture, allowing the use of mathematical concepts in various cultural contexts. And thirdly, aspects of human thinking logic relevant in the ethnomathematics context include the ability to recognize patterns, connect mathematical concepts with cultural contexts, understand the relationship between numbers and symbols with cultural reality, and apply mathematical principles in daily life in ways consistent with cultural values and norms, including

understanding systems/structures and problem-solving.

At the same time, several things are recommended. Particularly, the research on the relationship between human thinking logic and the development of mathematical concepts in a broader society. This study could involve analyzing the historical development of mathematical concepts and how human thinking logic has influenced that development. It could also examine how new mathematical developments have affected logical thinking. Then, a study on the role of human thinking logic in using mathematical concepts in more specific cultures. This research could delve deeper into how human thinking logic influences the use of mathematical concepts in various cultural contexts, such as art, music, or specific cultural traditions. Also, the research on the aspects of human thinking logic relevant in a deeper ethnomathematics context. This study could focus on the most influential aspects of human thinking logic in understanding and using mathematical concepts in specific cultural contexts and how these aspects differ between cultures.

Supplementary Materials & Data Availability Statement: No supplementary materials are associated with this study.

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Appendix A

Example of a HOTS problem based on Batak Mandailing and Batak Toba ethnomathematics

HOTS Question

A craftsman of Batak Toba Ulos and Mandailing woven fabric creates repeating geometric patterns in the shape of triangles and rhombuses on the woven cloth. On one piece of *ulos* fabric, the pattern is as follows:

- (1) The first row consists of 3 motifs.
- (2) Each subsequent row increases by 2 motifs from the previous row.
- (3) The number of motifs in the 10th row will be used to determine the number of ornaments in a joint traditional ceremony between the Batak Mandailing and Batak Toba communities.

Questions:

- (1) Determine the number of motifs in the 10th row.
- (2) Calculate the total number of motifs from the first row to the 10th row.
- (3) Explain the relationship between this pattern and the logical thinking of the Batak people in creating cultural order.

Solution

- (1) Determining the number of motifs in the 10th row

Given:

First term $a=3$

Common difference $b=2$

Using the arithmetic sequence formula:

$$U_n = a + (n - 1)b$$

Substitution:

$$U_{10} = 3 + (10 - 1) \times 2$$

Result:

$$U_{10} = 3 + 18 = 21$$

Thus, the number of motifs in the 10th row is 21 motifs.

(2) Determining the total number of motifs up to the 10th row
Using the arithmetic series sum formula:

$$S_n = \frac{n}{2}(a + U_n)$$

Substitution:

$$S_{10} = \frac{10}{2}(3 + 21)$$

Result:

$$S_{10} = 5 \times 24 = 120$$

Thus, the total number of motifs is 120 motifs.

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