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Mathematical Reasoning in *Jemparingan*: An Ethnographic Study of Ratio, Acute Angles, and Integer Operations in a Javanese Archery Tradition

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Abstract

Traditional cultural practices have become a major focus in the study of ethnomathematics. However, there is still relatively little empirical research that systematically identifies the mathematical concepts embedded in traditional Javanese games. Therefore, this study aims to identify and analyze the mathematical concepts embedded in *Jemparingan*, a traditional Yogyakarta archery game, and to examine its relevance to mathematics learning. This research employed a qualitative ethnographic approach. Data were collected through participatory observation, field documentation, and semi-structured interviews with *Jemparingan* practitioners. The data was analyzed using thematic analysis, which includes data organization, in-depth reading and data recording, coding, and data interpretation. The findings revealed three mathematical concepts: proportional relationships in equipment measurement, acute angles in bow positioning, and integer operations in score calculation. These patterns are closely associated with the Javanese philosophy of *hening-hening* (inner calmness), which emphasizes calmness and balance. Overall, this study contributes to ethnomathematics by providing empirical evidence that traditional games can function as authentic representations of mathematical thinking while supporting appreciation of local cultural heritage. These findings encourage educators to consider the integration of local culture into more meaningful mathematics instruction.

Keywords: Ethnomathematics; Javanese culture; Jemparingan, Mathematical concepts; Mathematics learning

Introduction

In mathematics education, the use of instructional media and teaching aids plays a crucial role in facilitating students' conceptual understanding and engagement. Research has shown that teachers who rarely incorporate media or manipulatives into mathematics instruction tend to create learning environments that are less engaging and less conducive to meaningful understanding of mathematical concepts (Dan & Luân, 2025). Consequently, students may experience difficulties in developing a deep and comprehensive understanding of mathematics (Schoenherr et al., 2024). Conversely, studies have demonstrated that traditional games can enhance students' logical-mathematical intelligence, participation, and engagement during classroom learning activities (Liang & Sitthiworachart, 2023; Zayyadi et al., 2025). These findings suggest the importance of integrating cultural elements, including ethnomathematics, into innovative learning approaches aimed at strengthening students' mathematical competencies.

Ethnomathematics provides a theoretical framework for understanding mathematics as a culturally situated form of knowledge. According to Ambrosio and Paulo (2001) and Rosa et al. (2016), the ethnomathematics program recognizes the existence of multiple ways of doing mathematics by considering how diverse social groups develop, apply, and negotiate mathematical knowledge within their cultural practices. From this perspective, mathematics is not limited to formal academic settings but is also embedded in everyday cultural activities. Therefore, integrating ethnomathematics into classroom instruction is essential because it responds to the need for more meaningful and engaging mathematics learning while simultaneously utilizing cultural practices as valuable sources of mathematical knowledge.

Previous studies have explored ethnomathematical aspects embedded in various traditional games, including gobak sodor (Sunni & Pradipta, 2024; Deda et al., 2024), *congklak* (Tampubolon et al., 2023; Khasanah et al., 2023), *engklek* (Supriadi, 2019), *kelereng* (Robawati et al., 2025; Amsikan et al., 2023), i*ngkau* (Oktavia et al., 2025), and *bekel* ball (Setyowati et al., 2025). Research conducted by Winardi and Jupri (2025) revealed that traditional games contribute positively to students' conceptual understanding, learning outcomes, creativity, character development, mathematical connections, and meaningful learning experiences. Similarly, Lestari et al. (2024) found that traditional games increase students' engagement and improve their understanding of mathematical concepts. Collectively, these studies indicate that traditional games contain identifiable mathematical structures that can serve as rich contexts for mathematics learning.

Despite this growing body of research, most ethnomathematical investigations of traditional games have focused primarily on counting activities, board movements, or general geometric patterns. Comparatively little attention has been devoted to traditional games involving bodily techniques, equipment adjustment, spatial positioning, and structured scoring systems. Consequently, traditional cultural practices characterized by strong philosophical values and regional identities, such as *Jemparingan*, remain underexplored from the perspective of specific mathematical concepts and representations.

From an ethnomathematical standpoint, cultural practices are not merely forms of social heritage but also activities that implicitly involve mathematical reasoning. Such reasoning may manifest through measurement, spatial orientation, proportional relationships, comparison, and numerical calculations. Traditional games, in particular, require participants to interact with objects, positions, distances, and scoring mechanisms, allowing mathematical concepts to emerge naturally within the cultural activity itself. As a traditional archery practice deeply rooted in Javanese cultural values, *Jemparingan* provides a distinctive context in which physical measurement, spatial positioning, and numerical scoring are continuously enacted during gameplay. Traditional games represent important cultural assets that embody values and knowledge worthy of preservation and transmission to future generations (Močinić & Brussich, 2023; Zuhri et al., 2023). Accordingly, Indonesian traditional games such as *Jemparingan* not only contain rich cultural elements but also possess considerable potential as relevant and engaging contexts for mathematics learning (Ibarra et al., 2020).

However, the increasing dominance of modern games has contributed to the gradual decline of traditional games among younger generations, despite their significance as cultural heritage (Taheri & Chahian, 2015; Yücesan et al., 2023). This situation highlights the importance of reintroducing traditional games within educational contexts, thereby enabling students to appreciate and practice the cultural values embedded within these traditions while simultaneously benefiting from their educational potential.

This study focuses on the ethnomathematical dimensions of *Jemparingan*, a traditional archery game in which participants aim arrows toward a target known as the *bandulan*. The *bandulan* consists of four colored sections red, yellow, white, and black each associated with a particular scoring value. The movements and techniques involved in *Jemparingan* have been shown to support the development of concentration, fine motor skills, visual acuity, self-confidence, and character formation among children (Islammeiliani et al., 2021). Unlike many traditional games that have primarily been examined through counting activities or geometric movement patterns, *Jemparingan* presents a unique combination of measurement practices, spatial positioning, and numerical scoring systems that potentially embody a broader range of mathematical concepts and representations. Furthermore, Prieto and Troncoso (2025) demonstrated that traditional games can be effectively integrated into mathematics instruction and positively influence students' mathematics learning outcomes. Therefore, investigating the mathematical elements embedded within *Jemparingan* may contribute to the development of culturally responsive mathematics education while simultaneously promoting the preservation of local cultural heritage.

Although ethnomathematics research on traditional games continues to expand, limited attention has been given to the systematic identification of mathematical concepts embedded in *Jemparingan* and to the exploration of how these concepts can support culturally contextualized mathematics learning. This limitation constitutes the primary research gap addressed by the present study. Accordingly, this study examines mathematical concepts embedded in *Jemparingan*, particularly comparison, acute angles, and integer operations, in order to provide new insights into the manifestation of mathematical ideas within local cultural practices. In

addition, the study seeks to offer recommendations for teachers in designing innovative mathematics instruction that integrates cultural elements while contributing to the preservation of traditional games (Deda et al., 2024). By positioning traditional games as meaningful learning resources, this research contributes to the advancement of contextual and culturally grounded mathematics education. More specifically, the integration of *Jemparingan* into mathematics learning has the potential not only to enhance students' understanding of mathematical concepts but also to strengthen their connection to local cultural heritage, thereby fostering a more holistic, meaningful, and culturally responsive approach to mathematics education.

Methods

This study employed a qualitative ethnographic approach to investigate the cultural practices embedded in *Jemparingan* and to identify the mathematical concepts manifested within these practices. Ethnography was considered appropriate because it enables an in-depth exploration of cultural activities, meanings, and social interactions within their natural settings (Júnior et al., 2023). Through participatory observation, semi-structured interviews, and document analysis, the study sought to understand how mathematical ideas emerge from the practices, tools, and traditions associated with *Jemparingan*.

Fieldwork was conducted between November and December 2025 at two sites in Yogyakarta, Indonesia: The Sonobudoyo Museum and Sasana *Jemparingan* Sambisena, both of which play important roles in preserving and promoting Javanese cultural heritage. The Sonobudoyo Museum was selected because it maintains an extensive collection of Javanese historical and cultural artifacts, providing valuable resources for understanding the historical development and cultural significance of *Jemparingan*. The museum also facilitated access to curatorial expertise regarding the historical context and evolution of this traditional practice. Sasana *Jemparingan Sambisena* was selected because it is an active community organization dedicated to preserving and practicing the traditional Mataraman style of archery according to the established rules of Jemparingan. This setting enabled direct observation of gameplay and provided opportunities to collect detailed information from experienced practitioners actively engaged in the tradition.

Data were collected through participatory observation, semi-structured interviews, and documentation to obtain a comprehensive understanding of the ethnomathematical dimensions of *Jemparingan*. Participatory observation was conducted to gain direct insight into gameplay procedures, player interactions, equipment use, and the broader sociocultural context in which *Jemparingan* is practiced. The observation phase consisted of two sessions. The first observation session was conducted at the Sonobudoyo Museum over a period of seven hours. During this session, the researchers examined visual representations and archival materials related to *Jemparingan* and conducted informal discussions with the museum curator to obtain historical information regarding the development of the game. The second observation session took place at Sasana Jemparingan Sambisena and lasted approximately nine hours. During this

period, the researchers observed eight *Jemparingan* practice sessions, focusing on gameplay procedures, equipment characteristics, player positioning, scoring mechanisms, and interactions among participants.

Semi-structured interviews were conducted with three key informants selected through purposive sampling based on their knowledge and involvement in *Jemparingan* practices. The participants included:

1. A *Jemparingan* practitioner at Sasana Sambisena, who provided technical explanations regarding gameplay procedures, equipment uses, and shooting techniques;
2. The chairperson of Sasana Sambisena, who offered sociocultural interpretations of the tradition and its contemporary development; and
3. A curator from the Sonobudoyo Museum, who provided historical and cultural perspectives concerning the origins and evolution of *Jemparingan*.

The interviews were conducted in several stages to allow for clarification and validation of emerging findings throughout the research process. Finally, documentary data were collected in the form of field notes, photographs, video recordings, museum archives, and other relevant records related to traditional games in Yogyakarta. These materials served as acute evidence and supported source triangulation, thereby strengthening the credibility and contextual richness of the findings.

The collected data, consisting of field notes, interview transcripts, and documentary materials, were analyzed using thematic analysis following the procedures described by Ahmed et al. (2025) and Kushnir (2025). The analytical process involved data organization, repeated reading and familiarization, coding, categorization, theme development, and interpretation. Data analysis was conducted concurrently with data collection to preserve contextual depth and facilitate continuous refinement of interpretations.

The first stage involved open coding, in which meaningful units of data were identified and labeled. Several initial codes emerged during this process, including game rules, community customs, cross-legged sitting positions, mat dimensions, shooting distance, target height, arrow dimensions, player height, proportional suitability of equipment, comparison concepts, bow position, bow inclination, shooting direction, scoring systems, total scores, and integer operations. The second stage involved axial coding, during which conceptually related codes were grouped into broader categories to reveal relationships among game structures, player strategies, and mathematical interpretations. Through this process, three major analytical themes were identified:

1. Measurement of game properties, encompassing dimensions, proportionality, and size relationships associated with equipment and gameplay;
2. Game strategy, involving spatial positioning and directional considerations during shooting; and
3. Numerical calculation, involving scoring procedures and arithmetic operations used to determine game outcomes.

The synthesis of these themes revealed that *Jemparingan* embodies several mathematical concepts, particularly ratio, acute angles, and integer operations. These concepts emerged naturally through participants' interactions with equipment, spatial arrangements, and scoring systems, illustrating how mathematical reasoning is embedded within cultural practice, summarized in Table 1.

Table 1. Key Analytical Themes and Mathematical Concepts in *Jemparingan*

Theme	Description	Mathematical Concepts
Jemparingan Property Measurement	The equipment and physical properties used in *Jemparingan* involve various measurements, dimensions, and proportional relationships that ensure appropriate functionality and balance.	Ratio
Strategy in the Game	Successful gameplay requires strategic positioning and directional control of the bow and arrow to accurately hit the target (*bandulan)*.	Acute Angles
Number Calculation	Scores obtained during gameplay are calculated and interpreted through arithmetic procedures.	Integer Operations

To enhance the credibility and trustworthiness of the findings, data triangulation was employed by systematically comparing information obtained through observations, interviews, and documentary evidence. Each mathematical indication identified during observation such as proportional equipment dimensions, bow inclination, and scoring calculations was verified through interview data and supporting photographic documentation to ensure consistency across multiple sources.

During the triangulation process, differences emerged regarding the position of the bow in *Jemparingan*. Historical documents and official records described the bow as being held horizontally, whereas field observations revealed that practitioners commonly positioned the bow at approximately the one o'clock angle. Further investigation clarified that the horizontal technique is known as *Jegulan*, a particular form of *Jemparingan* characterized by a horizontal bow orientation. Contemporary *Jemparingan* practice, however, predominantly employs a bow position inclined toward the one o'clock direction. This discrepancy illustrates the dynamic nature of cultural practices and highlights the importance of triangulation in achieving accurate cultural interpretation. Through continuous comparison of observational, interview, and documentary data, the study sought to ensure that the identified mathematical concepts reflected authentic cultural practices rather than solely the researchers' subjective interpretations.

Results

This study identifies *Jemparingan* as a multivalent cultural practice that integrates historical traditions, philosophical values, material artifacts, and mathematical reasoning. As a traditional archery practice rooted in the cultural heritage of Yogyakarta, *Jemparingan* has maintained continuity through its distinctive terminology, standardized procedures, equipment

specifications, and scoring conventions. These cultural elements not only sustain the practice as a form of intangible cultural heritage but also embody mathematical relationships that emerge naturally through participation.

The findings are organized into two interconnected dimensions. The first dimension examines the historical, sociocultural, and philosophical foundations of *Jemparingan* based on documentary sources and ethnographic interviews with participants who provided informed consent in accordance with established research ethics procedures. The second dimension explores the ethnomathematical characteristics of the practice by identifying mathematical concepts embedded in gameplay, particularly ratio, acute angles, and integer operations. Together, these findings demonstrate that *Jemparingan* functions not only as a cultural activity but also as a meaningful context through which mathematical ideas are generated, enacted, and transmitted. Consequently, the practice offers considerable potential for the development of culturally responsive mathematics education grounded in ethnomathematical principles.

Jemparingan: Historical, Cultural, and Philosophical Foundations

The precise historical origin of *Jemparingan* remains uncertain because documentary evidence is limited and historical accounts suggest that the practice may have emerged in either Yogyakarta or Surakarta. Within the Yogyakarta tradition, however, it is widely recognized as *Jemparingan Gaya Mataram*, a traditional archery practice associated with the cultural legacy of the Mataram Kingdom. Unlike modern competitive archery, which is generally performed in a standing position, *Jemparingan* requires participants to shoot while seated cross-legged or kneeling. This distinctive bodily posture reflects broader philosophical and cultural values embedded within the practice.

Historical accounts indicate that the development of *Jemparingan* within the Yogyakarta Sultanate can be traced to the reign of Sri Sultan Hamengku Buwono I, who promoted archery as a means of cultivating noble character. The practice emphasizes values such as concentration, enthusiasm, self-confidence, and responsibility. Significantly, success in *Jemparingan* is traditionally understood to depend less on visual aiming and more on the archer's inner sensitivity and concentration. This orientation reflects a philosophical perspective in which focused intention serves as a metaphor for pursuing life goals with determination and self-discipline.

The philosophical foundation of *Jemparingan* is closely associated with four interrelated Javanese values: *sawiji*, *greget*, *sengguh*, and *ora mingkuh*. The concept of *sawiji* refers to complete concentration and unity of mind, which practitioners regard as essential for accurate shooting. This concentration extends beyond cognitive focus and is often interpreted as a spiritual alignment between the individual and the divine. The concept of *greget* represents enthusiasm and inner motivation, *sengguh* reflects self-confidence grounded in humility and self-awareness, and ora *mingkuh* signifies responsibility, perseverance, and commitment. Together, these values position *Jemparingan* as a cultural practice aimed at character formation rather than merely physical skill development.

The symbolic dimensions of *Jemparingan* are also evident in its bodily techniques and material artifacts. The cross-legged sitting position may be interpreted as a form of meditation that supports concentration and self-control. Likewise, the bow and arrow symbolize purposeful direction and thoughtful action, representing the individual's effort to navigate life toward meaningful goals. Although the distance between the archer and the target (approximately 30–33 meters) does not appear to carry explicit philosophical significance, other aspects of the practice reflect historical symbolism. For example, the common use of four arrows per round in Yogyakarta is believed to be associated with the four-arrow emblem appearing on medals during the reign of Sri Sultan Hamengku Buwono VIII.

These findings demonstrate that *Jemparingan* constitutes a complex cultural system in which physical action, symbolic meaning, and moral values are closely interconnected. From an ethnomathematical perspective, such cultural structures provide an important foundation for understanding how mathematical reasoning emerges within socially organized practices.

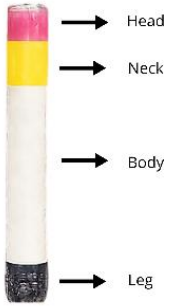
Jemparingan Equipment and Material Culture

The implementation of *Jemparingan* requires several specialized forms of equipment, including the *gandewa* (bow), bowstring, arrows, target (*bandulan*), seating cushion, and playing arena (*sasana*) presented in Table 2. Each component possesses particular dimensions and functional characteristics that support gameplay. Importantly, many of these physical characteristics involve measurement, proportional relationships, and spatial organization, thereby providing opportunities for mathematical interpretation.

Table 2. Equipment And Gameplay Mechanics of *Jemparingan*

Component	Description	Image Illustration
Sasana	Sasana is the arena where *Jemparingan* is played. This arena is generally a large, open field with no standard dimensions, but it is designed so players can aim at a target (*bandulan*) at a distance of 30-33 meters.	 *Jemparingan* Players aim at the target
Gandewa	*Gandewa* is a bow used when playing *Jemparingan*. The length of the *gendewa* is generally adjusted to the height of the archer, because shorter *gendewa* are considered less	

Component	Description	Image Illustration
	common. The *Gandewa* is equipped with a bowstring that is about three fingers longer than the height of the *Gandewa*.	*Gandewa* is being played in *Jemparingan*  The height of the *Gandewa* corresponds to the height of the player
Arrowhead	Arrows are made to be half the length of the player's arm span, or with a maximum length of approximately 70 cm and a maximum diameter of 6 mm.	 The size of the arrow is half the length of the player's arm span  Arrowhead

Component	Description	Image Illustration
Target / Objective (*Bandulan*)	The *bandulan* serves as the target in the game of *Jemparingan*. It is generally made of straw, lemongrass stalks, or reeds, and is arranged in four color sections with specific meanings: red symbolizes the head and is 3 cm long, yellow symbolizes the neck and is 3 cm long, white is 22 cm long, and black is at the bottom and is 2 cm long. Overall, the *bandulan* is about 30 cm long with a maximum diameter of 3.5 cm, and is hung at a height of about 150-155 cm from the ground.	 *Bandulan* on *Jemparingan*
Seat Cushion	The seat cushion used in *Jemparingan* is usually a sponge with a maximum thickness of 3 cm, although in practice, players are also allowed to use none.	 Seat cushion for the game of *Jemparingan*

The *sasana* serves as the playing arena and is generally an open space designed to accommodate shooting distances of approximately 30–33 meters. The *gandewa* is traditionally constructed in proportion to the player's body dimensions, while the arrow length is adjusted according to arm span and technical requirements. Similarly, the *bandulan* target is structured according to specific dimensions and color-coded scoring zones. These findings indicate that measurement and proportional reasoning are embedded in the material design of the game and are not merely external mathematical interpretations imposed by researchers.

Furthermore, competition categories are organized according to target distance, with 30-meter classes for adults, 20-meter classes for adolescents, and 15-meter classes for children. This classification reflects an implicit understanding of variation, proportionality, and adaptation based on age-related physical capabilities.

Ratio as an Ethnomathematical Representation

In the game of *Jemparingan*, several pieces of equipment are required, including a *Gandewa* (bow) and arrows. The *Gandewa* (bow) must be made to a specific size, measured by the player's height. To clarify the relationship between the traditional *Gandewa* (bow) instrument and the player, a visual representation was created showing the vertical ratio between the player's height and the length of the *Gandewa* (bow), as illustrated in Figure 1.

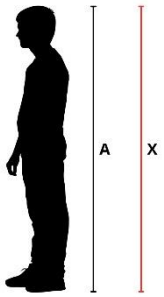


Figure 1. Illustration comparing a player's height to the length of a *Gandewa* (bow)

In the figure, variable A represents the player's height, while variable X represents the length of the *Gandewa* (bow). Based on visual observations supported by interviews with *Jemparingan* practitioners, it was found that the starting and ending points of measurement from the player's height to the length of the *Gandewa* (bow) are in relatively parallel positions, both measured from the ground surface to the highest point of each object. This finding indicates that the length of the *Gandewa* (bow) tends to adjust to the player's height so that both are nearly equal in size. Mathematically, this relationship can be expressed in the following equation:

$$A : X = 1 : 1$$

This means that the ratio of the player's height to the length of the bow is 1:1. For example, if the player is 150 cm tall, the *Gandewa* (bow) used is also 150 cm. This calculation assumes that the length of the *Gandewa* (bow) used is proportional to the player's height. Next, to examine the relationship between the size of *Jemparingan* equipment and the players' body dimensions, a visual representation of the players' arm span and arrow length was created, as shown in Figure 2.

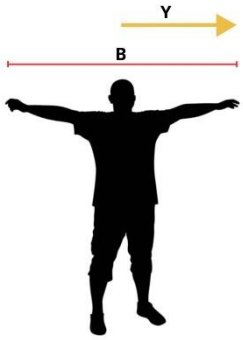


Figure 2. An illustration comparing the length of a player's arm span with an arrow

In the figure, variable B represents the player's arm span, measured from the tip of the left index finger to the tip of the right index finger, while variable Y represents the length of the arrow. Based on visual observations, reinforced by interviews with *Jemparingan* practitioners, it was found that the arrow is shorter than the player's arm span. The arrow appears to cover approximately half the length of the arm span, indicating a suitable size relationship between the equipment used and the player's range of motion. This size relationship can be mathematically expressed as follows:

$$Y : B = 1 : 2$$
$$Y = 1/2\, B$$

This means that if we want to find the arrow length that best matches the player's arm span, we can use that ratio. The following is an example of the illustration:

Table 3. Illustration of Ratio in the Length of Arrows

Player's arm span	Ratio Calculation	Estimated arrow length
140 cm	$\frac{1}{2} \times 140\ cm$	70 cm
150 cm	$\frac{1}{2} \times 150\ cm$	75 cm, adjusted to max. 70 cm
160 cm	$\frac{1}{2} \times 160\ cm$	80 cm, adjusted to max. 70 cm

Table 3 shows that the relationship between the player's arm span and arrow length can be initially represented through a proportional model, in which the arrow length is approximately half of the player's arm span. This model indicates the presence of comparative reasoning in determining equipment size. However, the field data show that this relationship is not applied as an exact mathematical formula. In actual *Jemparingan* practice, arrow length is adjusted by considering ergonomic and technical factors, such as the player's comfort, body posture, drawing position, and stability when releasing the arrow. Thus, although the ratio

model provides a mathematical representation of the relationship between body measurement and equipment size, the actual practice demonstrates a flexible proportional relationship shaped by practical experience and playing technique.

The concept of proportion in *Jemparingan* is evident in two main relationships: the relationship between the length of the *gandewa* and the player's height, and the relationship between the arrow length and the player's arm span. These relationships show that the equipment used in *Jemparingan* is not selected arbitrarily but is adjusted to the player's body dimensions and playing technique. An arrow that is too short may limit the drawing position, while an arrow that is too long may reduce balance, comfort, and stability when released. Therefore, the selection of arrow length is made by considering the player's arm span, body posture, and shooting comfort. In this context, the ratio does not function as a rigid mathematical formula, but as a practical proportional relationship that supports movement efficiency, shot stability, and the appropriate use of equipment. This finding is supported by the consistency between field observations, practitioners' explanations, and visual documentation, which indicate that the proportional relationship between body measurement and equipment size is not incidental, but reflects a form of comparative reasoning embedded in the practice of *Jemparingan*.

Acute angle

The findings indicate that *Jemparingan* involves a form of embodied geometric reasoning that can be interpreted through the concept of acute angles. During gameplay, participants employ several technical strategies to improve shooting accuracy, including selecting appropriate equipment, maintaining an upright seated posture, positioning the arrow parallel to the cheek, extending the non-dominant arm, and slightly inclining the *gandewa* (bow) while aiming. Among these techniques, the inclination of the bow represents a particularly significant ethnomathematical feature because it reflects an intuitive understanding of angular relationships developed through repeated cultural practice.

Preliminary observations and historical interview data revealed variations in bow positioning across different periods of *Jemparingan* practice. Historical accounts suggest that earlier forms of *Jemparingan* frequently employed a horizontal bow position, commonly known as *jegulan*. However, field observations of contemporary practice, supported by practitioners' explanations and visual documentation, indicate that players now more commonly incline the *gandewa* toward what they describe as the "one o'clock position" during aiming. Although practitioners generally do not express this technique using formal geometric terminology, their descriptions and bodily movements reveal an implicit awareness of angular orientation as a means of controlling shooting direction and maintaining stability.

Figure 3 illustrates the angular change occurring during the aiming process. In this representation, line A denotes the initial vertical position of the *gandewa*. As the player prepares to release the arrow, the bow is tilted toward the right, forming an angle that can be approximated as 30°. From a mathematical perspective, this inclination produces an acute angle because its measure is less than 90°. The geometric significance of this position lies not only in

the resulting angle itself but also in the player's ability to consistently reproduce the inclination through bodily experience and practical knowledge.

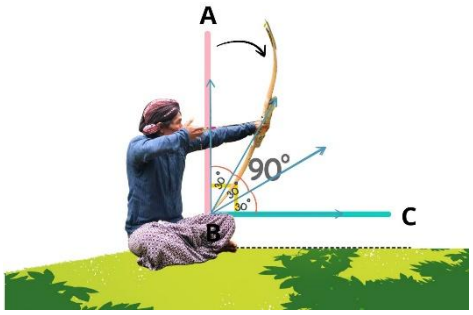


Figure 3. The acute angle found in the game of *Jemparingan*

To clarify this relationship, the bow position may be represented using the familiar structure of a clock face (Figure 4). The vertical position of the bow corresponds to the twelve o'clock direction, while the recommended aiming position corresponds to the one o'clock direction. Within a circular representation divided into twelve equal sectors, the movement from twelve o'clock to one o'clock corresponds to an angle of approximately 30°.

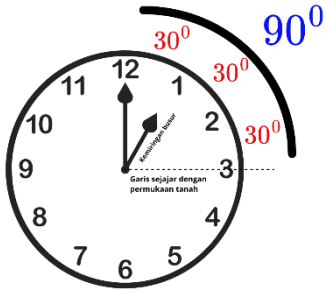


Figure 4. Illustration of angles with a clock hand

Similarly, movement toward the two o'clock and three o'clock positions would correspond to approximately 60° and 90°, respectively. Through this representation, the practical terminology used by players can be translated into formal geometric language without disregarding the cultural context from which it originates.

Importantly, the ethnomathematical significance of this finding extends beyond the identification of an acute angle. The practice demonstrates how geometric reasoning emerges through embodied action rather than through formal measurement instruments or explicit mathematical instruction. Players do not determine the bow's inclination using protractors or numerical calculations; instead, they rely on accumulated experience, observation, and community knowledge to estimate and reproduce a stable shooting position. In this sense, angle estimation functions as a culturally situated mathematical practice embedded within the performance of *Jemparingan*.

From a mathematics education perspective, this finding illustrates how geometric concepts can be connected to meaningful cultural activities. The "one o'clock position"

provides a familiar and contextually grounded representation through which students can explore concepts such as angle measurement, angle classification, rotational movement, and spatial orientation. Consequently, *Jemparingan* offers a culturally authentic context for introducing geometric reasoning while simultaneously preserving local knowledge and traditions.

Integer Operations

Another mathematical concept embedded in *Jemparingan* is integer operations, which emerge through the scoring system used to determine player performance. Each target zone on the *bandulan* is assigned a specific numerical value, and players accumulate points based on the locations struck by their arrows. As a result, numerical calculation becomes an integral component of gameplay rather than a separate activity performed outside the cultural practice. Table 4 presents the scoring values assigned to each target zone. Hits on the head region receive the highest score (+3), followed by the neck (+2) and body (+1), whereas hits on the lower section of the target result in a penalty score (-1). Through repeated rounds of play, participants continually combine positive and negative values to determine their cumulative scores.

Table 4. Score obtained according to target

Target Zone	Score
Head (e.g., A)	+3
Neck (e.g., B)	+2
Body (e.g., C)	+1
Leg (e.g., D)	-1

For example, a player who scores $+3$ on the first shot, $+1$ on the second shot, $+1$ on the third shot, and -1 on the fourth shot obtains a total score of $3 + 1 + 1 - 1 = 4$.

This procedure illustrates the practical application of integer addition and subtraction within the game context. More generally, the total score obtained by a player can be represented as:

$$3A + 2B + C - D = Total\ score$$

where A, B, C, and D represent the number of arrows striking the head, neck, body, and lower target zones, respectively.

From an ethnomathematical perspective, the scoring system demonstrates how numerical reasoning is embedded within cultural activity. Players continuously perform arithmetic operations while monitoring their performance, comparing results with other participants, and evaluating strategic decisions during successive rounds. Although these calculations are rarely articulated using formal mathematical language, they require the practical use of integer concepts, including addition, subtraction, comparison, and cumulative calculation.

The convergence of observational data, interview findings, and score records indicates that participants engage in ongoing quantitative reasoning throughout gameplay. Positive scores are accumulated when arrows strike higher-value target zones, whereas lower-value or penalty

scores reduce the total score. Consequently, players must mentally coordinate gains and losses while tracking their overall standing. This process illustrates that integers function not merely as symbolic representations but as operational tools for decision-making and performance evaluation within the game.

The educational significance of this finding lies in the contextual nature of the mathematical activity. Rather than encountering integer operations through abstract numerical exercises, learners can observe how addition and subtraction emerge naturally within a culturally meaningful environment. Such contexts provide opportunities to connect formal mathematical concepts with lived experiences, thereby supporting the development of meaningful mathematical understanding. In this regard, the scoring mechanism of *Jemparingan* exemplifies how ethnomathematical practices can serve as bridges between cultural knowledge and school mathematics, enabling students to recognize mathematics as a human activity embedded within everyday cultural practices.

Discussion

The findings of this study demonstrate that *Jemparingan* is not merely a traditional recreational activity but a complex cultural practice in which mathematical reasoning is intertwined with Javanese philosophical values. Through ethnographic investigation, this study identified the presence of ratio, acute-angle reasoning, and integer operations embedded within the material artifacts, bodily techniques, and scoring mechanisms of the game. These findings contribute to the growing body of ethnomathematics research by illustrating how mathematical ideas emerge from culturally situated activities and are enacted through participation rather than formal mathematical instruction.

Previous ethnomathematics studies have documented a wide range of mathematical concepts embedded in traditional Indonesian games. For example, *gobak sodor* has been associated with vector concepts (Sunni & Pradipta, 2024) and geometric reasoning (Deda et al., 2024), while *congklak* has been linked to arithmetic operations (Tampubolon et al., 2023) and modular arithmetic (Khasanah et al., 2023). Similarly, *engklek* has been shown to support creative mathematical thinking, geometric reasoning, and algebraic understanding (Supriadi, 2019). Research on marbles (*kelereng*) has identified applications of basic algebraic concepts (Robawati et al., 2025), whereas the *ingkau* game has been associated with length measurement, proportional reasoning, parallelism, angles, cylinders, and right triangles (Oktavia et al., 2025). In addition, the *bekel* ball game has been reported to introduce concepts related to multiples of numbers (Setyowati et al., 2025). Extending this literature, the present study demonstrates that *Jemparingan* uniquely integrates proportional relationships, embodied angle estimation, and integer reasoning through equipment design, shooting techniques, and target-based scoring systems.

A closer examination of the findings reveals that the identified mathematical concepts perform functional roles within the practice of *Jemparingan*. Ratio is evident in the proportional relationships between players' body dimensions and the equipment they use, particularly in the

correspondence between body height and bow length, as well as between arm span and arrow length. These proportional relationships are not expressed through formal mathematical formulas by practitioners; rather, they emerge through practical judgments developed within the community. Such findings suggest that players engage in comparative reasoning when selecting and adjusting equipment to achieve balance, comfort, and shooting efficiency. Consequently, proportional reasoning in *Jemparingan* functions as a form of embodied mathematical knowledge grounded in experience and cultural practice.

Similarly, the concept of acute angles emerges through the positioning of the *gandewa* during aiming. Contemporary practitioners commonly orient the bow toward what they describe as the "one o'clock position," which corresponds approximately to a 30° inclination from the vertical. Importantly, players do not determine this position through formal geometric measurement. Instead, they develop a shared understanding of the appropriate inclination through observation, practice, and participation in the community. This finding illustrates how geometric reasoning can emerge through embodied action and spatial awareness. From an ethnomathematical perspective, the bow's orientation represents more than a geometric object; it constitutes a culturally transmitted technique through which players intuitively estimate and reproduce angular relationships in pursuit of accuracy and stability.

The scoring mechanism of *Jemparingan* provides a further example of culturally embedded mathematical reasoning. Players continuously perform addition and subtraction while accumulating points across multiple rounds. Positive and negative scores are assigned according to the target zone struck by the arrow, requiring participants to monitor cumulative totals and evaluate their performance relative to competitors. Although these calculations may appear simple from a formal mathematical perspective, they demonstrate how integer operations are enacted in meaningful contexts where numerical reasoning serves practical purposes. The findings therefore support the ethnomathematical view that mathematical thinking is not confined to school settings but is frequently embedded within everyday cultural activities and decision-making processes.

An important contribution of this study lies in revealing the inseparable relationship between mathematical reasoning and cultural philosophy within *Jemparingan*. The identified mathematical concepts do not operate independently of the cultural values that govern participation. Rather, ratio, angle estimation, and score calculation are performed within a philosophical framework characterized by *sawiji* (concentration), *greget* (enthusiasm), *sengguh* (self-confidence grounded in self-awareness), and *ora mingkuh* (responsibility and perseverance). These values shape how players engage with the game and influence the manner in which mathematical reasoning is enacted.

The relationship between concentration and angular positioning provides a particularly illustrative example. Accurate shooting requires players to maintain focus while consistently reproducing the bow inclination associated with the one o'clock position. Consequently, the geometric reasoning involved in aiming cannot be separated from the discipline and concentration emphasized within Javanese philosophy. Likewise, decisions concerning equipment proportions and score calculations are performed within a broader framework of

patience, self-control, and responsibility. In this sense, mathematical reasoning in *Jemparingan* is not merely a technical activity but a culturally mediated practice shaped by ethical and philosophical principles.

These findings reinforce the central premise of ethnomathematics that mathematical knowledge develops within cultural systems and acquires meaning through social practice. The mathematical structures identified in *Jemparingan* are not external interpretations imposed upon the game; rather, they emerge from the ways participants interact with equipment, space, movement, and scoring conventions. Understanding *Jemparingan* ethnomathematically therefore requires attention not only to the mathematical concepts embedded within the activity but also to the cultural values and meanings that guide their application.

Beyond its mathematical dimensions, *Jemparingan* also contributes to character formation and cultural transmission. The practice promotes values associated with concentration, perseverance, confidence, responsibility, humility, and mutual respect. The use of traditional attire serves as a symbol of respect for ancestors and cultural heritage, while the absence of rigid social hierarchies among participants reflects the Javanese principle of *andhap asor* (humility). Through participation, younger generations are exposed not only to traditional cultural practices but also to social norms and ethical values demonstrated by experienced practitioners.

These findings are consistent with previous studies suggesting that cultural heritage can support the development of social and emotional competencies, strategic thinking, problem-solving abilities, and interpersonal skills (Ashar et al., 2024). Traditional games have also been shown to strengthen resilience, self-esteem, confidence, cooperation, and independence among children (Mwinsa & Dagada, 2025), while simultaneously promoting values such as patriotism and sportsmanship (Deda & Disnawati, 2024). The coexistence of mathematical reasoning and character education within *Jemparingan* therefore highlights its educational significance beyond cultural preservation alone.

From a mathematics education perspective, the findings suggest that *Jemparingan* offers considerable potential as a culturally responsive learning resource. Contemporary mathematics education continues to face challenges related to student engagement and the contextualization of mathematical concepts (Li et al., 2024). The integration of ethnomathematical contexts such as *Jemparingan* may help address these challenges by connecting formal mathematics with students' cultural environments and lived experiences. Learning activities derived from *Jemparingan* could engage students in investigating proportional relationships between body measurements and equipment dimensions, exploring angle estimation through bodily movement and spatial orientation, and applying integer operations through authentic scoring situations. Such activities have the potential to promote conceptual understanding while simultaneously fostering appreciation of local cultural heritage.

Furthermore, the findings support calls for mathematics instruction that recognizes culture as a legitimate source of mathematical knowledge rather than merely a contextual backdrop for learning. By incorporating traditional practices into classroom activities, teachers can create opportunities for students to examine how mathematical ideas emerge from everyday

cultural experiences. This approach may contribute to more meaningful learning experiences and encourage students to view mathematics as a human activity that is socially and culturally situated.

Nevertheless, several limitations should be acknowledged. The study was conducted within a specific cultural community in Yogyakarta and focused primarily on qualitative interpretations of ethnographic data. Consequently, the findings should not be generalized to all forms of traditional archery or cultural practices. Future research may investigate ethnomathematical variations of *Jemparingan* across different regions, quantitatively examine players' strategic decision-making processes, or evaluate the effectiveness of *Jemparingan*-based instructional designs in classroom settings. Such studies would further strengthen understanding of the relationship between cultural practice, mathematical reasoning, and mathematics learning.

Overall, the findings indicate that *Jemparingan* represents a culturally embedded mathematical practice in which proportional reasoning, geometric thinking, and integer operations are enacted through meaningful participation. By revealing the interconnectedness of mathematical ideas, cultural values, and character formation, this study contributes to the advancement of ethnomathematics research and highlights the potential of local cultural heritage as a resource for culturally responsive mathematics education.

Conclusion

This study demonstrates that *Jemparingan* constitutes a culturally embedded mathematical practice in which mathematical reasoning emerges through participation in a traditional Javanese archery activity. Through an ethnographic exploration of gameplay procedures, equipment characteristics, scoring mechanisms, and practitioners' perspectives, the study identified three principal mathematical concepts embedded within the practice: ratio, acute angles, and integer operations. These concepts are manifested through the proportional relationships between players' body dimensions and equipment size, the angular positioning of the *gandewa* during aiming, and the cumulative scoring system used to determine performance outcomes. Collectively, these findings indicate that *Jemparingan* embodies forms of quantitative, spatial, and numerical reasoning that are developed and transmitted through cultural practice rather than through formal mathematical instruction.

Beyond the identification of mathematical concepts, the study highlights the inseparable relationship between mathematical reasoning and the philosophical values embedded in *Jemparingan*. The principles of *sawiji* (concentration), *greget* (enthusiasm), *sengguh* (self-confidence grounded in self-awareness), and *ora mingkuh* (responsibility and perseverance) shape how participants engage with the activity and influence the enactment of mathematical practices such as estimating angles, adjusting proportions, and evaluating scores. These findings reinforce the ethnomathematical perspective that mathematical knowledge is culturally situated and acquires meaning through social participation and shared cultural experience. Consequently, *Jemparingan* should be understood not only as a traditional game but also as a

cultural context in which mathematical ideas and cultural values are simultaneously produced, practiced, and transmitted.

The study contributes to the growing body of ethnomathematics research by extending existing investigations of traditional games beyond counting activities and general geometric patterns. In contrast to many previously studied games, *Jemparingan* demonstrates how mathematical reasoning can emerge through the interaction of bodily movement, material artifacts, spatial orientation, and structured scoring systems. The findings therefore provide additional evidence that local cultural practices can serve as valuable sources of mathematical knowledge and meaningful contexts for mathematics learning.

From a mathematics education perspective, the results suggest that *Jemparingan* offers considerable potential for the development of culturally responsive learning environments. The mathematical ideas embedded in the practice may be transformed into instructional tasks that support students' understanding of proportional reasoning, geometric concepts, and integer operations while simultaneously fostering appreciation of local cultural heritage. In this way, the integration of *Jemparingan* into mathematics education may contribute to more meaningful, contextualized, and culturally grounded learning experiences.

Several limitations should nevertheless be acknowledged. First, the ethnographic data were collected from practitioners within a specific cultural community in Yogyakarta; therefore, the findings do not necessarily represent all variations of *Jemparingan* practiced across Java or Indonesia. Second, the study focused on the identification and interpretation of mathematical concepts embedded in the cultural practice and did not include instructional interventions or empirical evaluations of learning outcomes. Consequently, the educational implications proposed in this study remain theoretical and exploratory.

Future research could extend this work in several directions. Comparative studies across different *Jemparingan* communities may reveal regional variations in mathematical practices and cultural interpretations. In addition, design-based and classroom-based research is needed to investigate how the identified concepts of ratio, acute angles, and integer operations can be transformed into effective learning activities and how such activities influence students' mathematical understanding, cultural awareness, and engagement. Such investigations would further strengthen the contribution of ethnomathematics to culturally responsive mathematics education and provide empirical evidence regarding the educational potential of local cultural heritage as a resource for mathematics teaching and learning.

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Conflicts of Interest

The authors state that there is no conflict of interest related to the publication of this manuscript. Furthermore, they affirm that all ethical considerations such as plagiarism, misconduct, data fabrication and/or falsification, duplicate publication and/or submission, and redundancy have been fully addressed.

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