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Ethnomathematical exploration: Mathematical concepts in the Kolong pigeon game

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Abstract

Ethnomathematics, as an interdisciplinary field, emphasizes the fundamental integration of mathematics with cultural practices and knowledge systems. Indonesia's multicultural context provides exceptional opportunities for ethnomathematical investigation, particularly within the domain of culturally embedded games and recreational practices. This study examines the mathematical concepts embedded within the Kolong pigeon game, a traditional cultural practice documented during a regional Kolong pigeon competition held in Gondoharum, Kudus, Jawa Tengah, Indonesia. Employing a qualitative research design grounded in realist ethnographic methodology, data were collected through structured interviews, systematic observation, and comprehensive documentation. Data validity was established through triangulation techniques, cross-referencing findings from interviews, observational field notes, and documentary evidence. Data analysis followed a qualitative analytical framework consistent with Cresswell's approach to qualitative data interpretation. The findings reveal that the Kolong pigeon game demonstrates extensive utilization of geometric concepts, particularly two-dimensional and three-dimensional spatial representations within the game arena. These include explicit applications of symmetry, rectangular and square configurations, cubic and cylindrical shapes. Additionally, the study identified significant implementation of angular concepts within the formal rules governing players' body positioning and spatial orientation. These findings advance ethnomathematical scholarship by illuminating mathematical structures within culturally contextualized games and provide empirically grounded resources for pedagogical integration of cultural games into mathematics instruction.

Keywords: Angle, Cultural Games, Ethnomathematics, Geometry, Kolong Pigeon Game

Introduction

Mathematics is fundamentally embedded within daily human activities across social and cultural contexts. The mathematical practices foundational to all societies encompass universal activities including calculation, spatial positioning, measurement, design, play, and explanation (Bishop, 1988). The reciprocal relationship between mathematical processes and cultural systems is conceptualized within the framework of ethnomathematics (D'Ambrosio, 1997). Ethnomathematics seeks to elucidate human knowledge, practices, and ideas as situated within diverse cultural environments (D'Ambrosio, 2018). This framework contributes significantly to multiple knowledge domains by articulating the essential relationship between cultural heritage and mathematical systems (Rosa & Orey, 2021). Within educational contexts, ethnomathematics proves pedagogically valuable by establishing connections between local cultural practices and mathematical problem-solving approaches, thereby addressing everyday contextual challenges (Aini et al., 2023; Faiza et al., 2023; Salma et al., 2022). Furthermore, ethnomathematical approaches facilitate student learning while simultaneously preserving cultural identity and fostering cultural continuity (Candrasari et al., 2023; Deda et al., 2024; Tamara et al., 2025).

Ethnomathematical scholarship encompasses diverse cultural artifacts and practices with explicit mathematical foundations. Exemplary contexts include batik patterns, traditional musical instruments, traditional foods, and traditional dances, all of which embody geometric mathematical concepts (Prahmana & D'Ambrosio, 2020; Rahmi et al., 2025; Putra & Ramdhani, 2025; Sulistyawati et al., 2025). Traditional architectural forms, including residential structures and mosque architecture, demonstrate sophisticated geometric design principles (Kho et al., 2025; Zuliana et al., 2023). Ceremonial and practical time-counting traditions employed in activities such as construction and agricultural practices encode mathematical concepts including modulo arithmetic, relational structures, temporal units, and multiples (Umbara et al., 2021; Umbara et al., 2025; Wiryanto et al., 2022).

A particularly significant domain of ethnomathematical investigation involves community-based games and recreational practices. A comprehensive literature review by Batiibwe (2024) established that cultural games represent the most extensively researched ethnomathematical context. Ethnomathematical investigations of cultural games have been conducted by scholars across multiple geographic regions. For instance, traditional games from Ghana including Alikoto, Pilolo, and Oware embed algebraic, geometric, and data-related mathematical concepts amenable to pedagogical integration in mathematics curricula (Owusu & Addo, 2023). The South African game Morabaraba incorporates numerical and geometric concepts that support secondary-level mathematics instruction through contextual adaptation (Meeran et al., 2024; Tachie & Galawe, 2021).

Within Indonesia's multicultural context, ethnomathematical investigations of cultural games reveal substantial conceptual diversity. The game Pacu Jalur incorporates three-dimensional tubular geometric forms applicable to developing mathematical connection skills in elementary mathematics instruction (Fendrik et al., 2020). The game Tong Tong Galitong Ji encompasses modular arithmetic (modulo 6 and modulo 3), fundamental arithmetic operations

including subtraction and multiplication, arithmetic sequences, and probabilistic concepts (Turmudi et al., 2021). The card game Gaple integrates set theory, addition, probability, and inequality concepts (Afandi et al., 2024). The game Tikam Bana embodies two-dimensional geometric elements (squares and trapezoids), integer concepts, and probabilistic reasoning (Rahmawati & Sulisti, 2025). Additional traditional games including Wayang Umbul, Dam-Daman, Jingklak, Congklak, Bekel, Penteng, Gobak Sodor, and Engklek serve as effective pedagogical instruments for developing students' logical-mathematical reasoning capabilities (Zayyadi et al., 2025). The accumulated scholarly attention to cultural games within Indonesian society demonstrates the substantial potential for ethnomathematical investigation within this context.

The Kolong pigeon game represents a traditional Indonesian cultural practice with demonstrated potential for mathematical investigation and pedagogical application. This game exploits the natural speed and agility of pigeons; consequently, enthusiasts of this practice are predominantly individuals with specialized pigeon-husbandry expertise (Yuniar & Mustaqim, 2021). The game has achieved significant prominence through national-level competitive competitions organized by the Persatuan Merpati Tinggi Indonesia (PMTI). Pigeons selected for competitive participation meet rigorous criteria encompassing genetic lineage quality, physical conformation, and wing morphology (Ramadhan et al., 2021). The game employs a competition arena consisting of four structural barrier poles configured to approximate a cubic spatial form. The arena incorporates square-shaped openings (termed kolong) positioned at superior and inferior orientations, with each corner structurally connected to barrier poles via rope systems. Male pigeons are released from a distance of approximately one kilometer from the arena, while players maintain directional control of female pigeons with the objective of attracting male pigeons into the arena. The competitive outcome is determined by which pigeon first descends into the superior kolong area and subsequently traverses to the ground level within the inferior kolong area.

The distinctive spatial configuration of the Kolong pigeon game arena particularly its approximate cubic form presents a compelling context for ethnomathematical investigation. Notably, no prior empirical study has systematically examined the mathematical structures inherent within this cultural practice. This research addresses a substantive scholarly gap by investigating how mathematical concepts are embedded within and operationalized through this locally situated cultural game. Beyond contributing to ethnomathematical scholarship, this investigation is anticipated to enrich the repertoire of culturally proximate contexts available for mathematics pedagogy, thereby facilitating more meaningful and culturally responsive mathematics instruction. Consequently, this study aims to systematically explore and explicate the mathematical concepts operationalized within the Kolong pigeon game.

Methods

This research employs a qualitative methodology grounded in ethnographic inquiry. Specifically, a realist ethnographic approach was adopted, wherein the researcher positions

himself as an objective third-party observer tasked with accurately reporting observed phenomena and participant narratives (Creswell, 2013). The ethnographic approach was selected for this investigation because it facilitates comprehensive understanding of cultural systems, thereby enabling rigorous exploration of embedded mathematical concepts within community practices.

Participant selection was conducted using purposive sampling methodology, a strategic technique employed to identify individuals possessing substantive knowledge of the research phenomenon and willingness to articulate their perspectives, insights, and experiential understanding (Sugiyono, 2023). Participant selection criteria prioritized individuals demonstrating both theoretical knowledge of Kolong pigeon game rules and practical experience as active participants in competitive settings. The research sample comprised three participants: one member of the competition organizational committee and two active practitioners in Kolong pigeon game competitions.

Data collection encompassed three complementary methodological instruments: structured interviews, systematic observation, and documentary evidence. Data collection was conducted during the Kolong pigeon competition held in Gondoharum, Kudus, Jawa Tengah, Indonesia, from June 6, 2025, through June 8, 2025. Observational data were systematically collected throughout the competitive event, with particular attention directed toward game rules, procedural steps, and practitioner behavioral patterns. Detailed field notes documented observed activities, participant interactions, and contextual information. Documentary evidence was obtained through photographic and videographic recording of competition proceedings. Concurrent with observational and documentary data collection, in-depth interviews were conducted to develop comprehensive understanding of the Kolong pigeon game. Interview protocols were structured according to the framework presented in Table 1.

Table 1. Interview Protocol Framework

No	Interview Point
1	Definition and types of Kolong pigeon game
2	Structural components of the Kolong pigeon game arena
3	Rules and procedural steps of the Kolong pigeon game

Data validity was established through methodological triangulation, a technique employing multiple data sources to cross-validate findings (Leavy, 2017). Triangulation was executed by examining congruence among interview data, observational field notes, and documentary evidence, all directed toward addressing the unified research focus. This triangulation approach was implemented to mitigate potential data bias and strengthen the credibility and reliability of the analytical findings. Finally, data analysis was conducted using a qualitative analytical framework adapted from Creswell (2014), as presented in Figure 1.

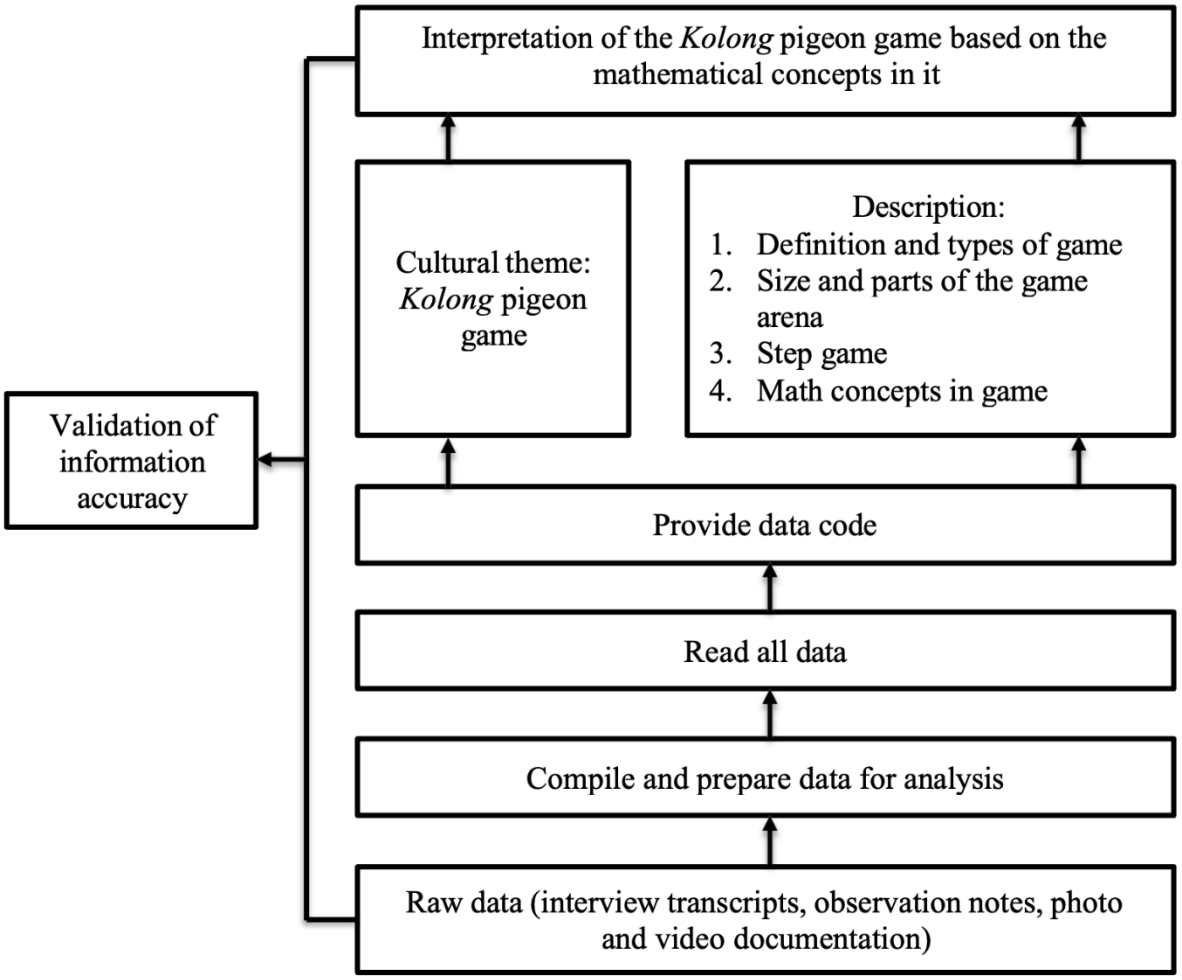


Figure 1. Data Analysis Procedure (Creswell, 2014)

Results and Discussion

Through systematic triangulation of interview data, observational field notes, and documentary evidence, comprehensive information was obtained regarding the definitional characteristics and typology of the Kolong pigeon game, dimensional specifications and structural components of the game arena, and procedural steps governing gameplay. These empirical data were subsequently analyzed and interpreted through the lens of mathematical concepts embedded within the Kolong pigeon game structure and practice.

Arena Components, Functional Characteristics, and Embedded Mathematical Concepts

The Kolong pigeon game constitutes a competitive activity emphasizing speed, precision, and agility in avian performance. This game frequently serves as the basis for organized competitions among pigeon enthusiasts. Two distinct typological variants exist: the free-Kolong pigeon game and the table-Kolong pigeon game. Both variants adhere to substantially similar regulatory frameworks, differing primarily in the configuration of the pigeon landing

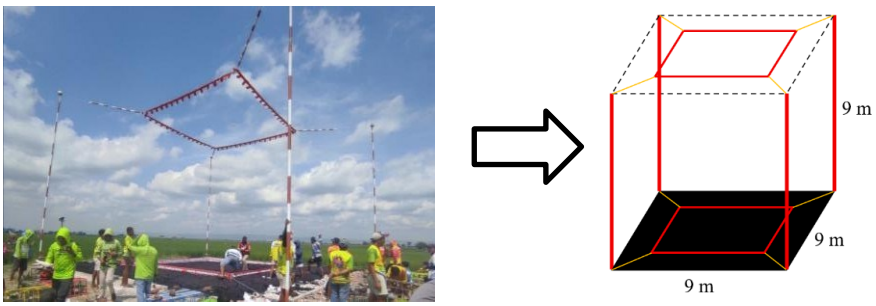
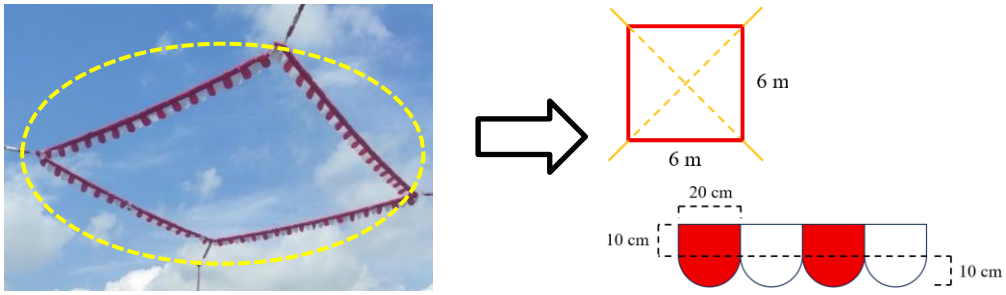
area. In the free-Kolong variant, the landing area provides direct ground contact for descending pigeons. Conversely, the table-Kolong variant incorporates an elevated platform (table) within the arena serving as the designated landing surface, thereby increasing competitive difficulty.

The Kolong pigeon game requires a specialized arena for competitive play. The arena employs four structural barrier poles configured to approximate a cubic spatial form. Square-shaped openings (termed kolong) are positioned at superior and inferior orientations, with each corner structurally connected to barrier poles via rope systems. The game arena is constructed on extensive open terrain such as agricultural fields or rice paddies. Arena construction adheres to specific dimensional requirements and structural component specifications. Each structural component serves distinct functional purposes. The dimensional specifications and functional characteristics of arena components were established through participant interviews, as illustrated in the following exchange:

Researcher: "What are the dimensional specifications of the Kolong pigeon game arena?"
Practitioner: "The standard total dimensions are 9 m × 9 m × 9 m."
Researcher: "Does the game arena incorporate essential structural components?"
Practitioner: "Yes. The essential components are the superior kolong, the inferior kolong, the landing area, and the barrier poles."
Researcher: "What are the dimensional specifications of each component?"
Practitioner: "The superior and inferior kolong measure 6 m × 6 m, the landing area measures 9 m × 9 m, and the barrier poles have a height of 9 m."
Researcher: "Do these essential arenas components serve specific functional purposes?"
Practitioner: "Yes. Each arena component serves critical functions for gameplay and competitive proceedings."
Researcher: "Could you elaborate on these functional purposes?"
Practitioner: "For example, the superior kolong and inferior kolong demarcate the spatial boundaries that pigeons must traverse. The landing area serves as the designated landing surface for pigeons. This applies to the free-Kolong pigeon game. In the table-Kolong variant, the landing area consists of an elevated platform termed patek. The barrier poles function to secure the rope systems forming the superior and inferior kolong boundaries."

The interview data establish that the Kolong pigeon game arena and its structural components adhere to specific dimensional requirements essential for gameplay integrity. The interview responses identified four essential arena components: the superior kolong, the inferior kolong, the landing area, and the barrier poles. Each component fulfills critical functional roles supporting Kolong pigeon game implementation and competitive proceedings. Analytical findings reveal that the Kolong pigeon game arena and its components operationalize multiple mathematical concepts. These mathematical concepts are systematically presented in Table 2.

Table 2. Mathematical Concepts Embedded in the Kolong Pigeon Game Arena

Kolong Pigeon Game Arena

Kolong Pigeon Game Arena The complete arena approximates a cubic form with dimensions of 9 m × 9 m × 9 m. The arena comprises four principal structural components: the superior kolong, the inferior kolong, the landing area, and the barrier poles. Each component serves essential functional purposes and operationalizes specific mathematical concepts.
Specific Arena Components


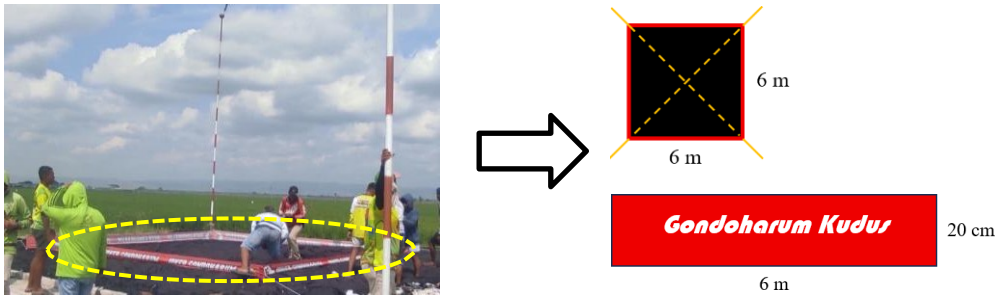
Superior Kolong

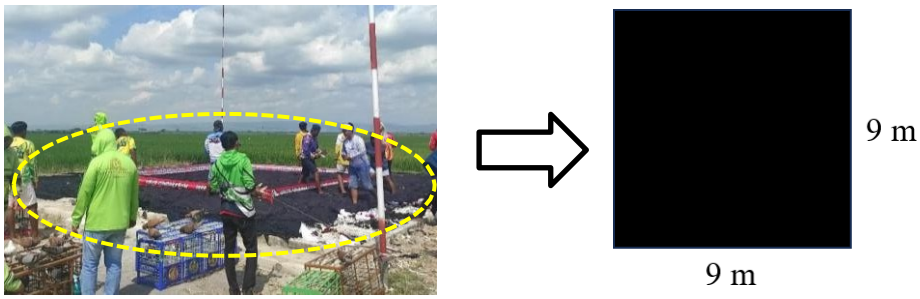
The superior kolong is bordered by a series of square flags with semicircular ends, arranged sequentially in alternating red and white colors. This superior kolong serves as a designated boundary that pigeons must enter when they begin their descent into the arena. Structurally, the superior kolong is a square with sides measuring 6 meters. The ropes connecting each corner of the kolong to the supporting poles demonstrate the application of folding symmetry in a square. Furthermore, the flags arranged along the boundary of the superior kolong combine two geometric shapes: a rectangle measuring 20 cm in length and 10 cm in width, and a semicircle with a radius of 10 cm.

Inferior Kolong

The inferior kolong serves as a boundary area that pigeons must enter when landing in the designated landing zone. This boundary is formed by a red rectangular cloth that typically bears the name of the arena or the location where the competition is held. Similar to the superior kolong, the inferior kolong is also a square with sides measuring 6 meters. The ropes connecting each corner of the inferior kolong to the barrier poles likewise illustrate the

application of folding symmetry in a square. In addition, the fabric used as the boundary on each side of the inferior kolong is rectangular in shape, measuring 6 meters in length and 20 centimeters in width.

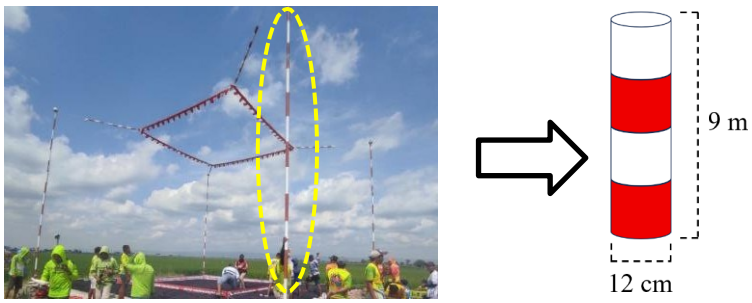




Landing Area

The landing area is constructed using a pile of rice husks or a mattress-like layer to prevent injury to the pigeons' feet upon landing. In the free-kolong pigeon competition, this area functions solely as the designated landing zone. However, in the table-kolong competition, an additional structure—a specialized table commonly referred to as patek—is provided as the landing platform. The landing area is square in shape, with each side measuring 9 meters. Consequently, its total area can be calculated as follows:

$9 \text{ m} \times 9 \text{ m} = 81 \text{ m}^2$.



Barrier Poles

The arena is bounded by four barrier poles, which are typically made of bamboo or iron and painted in red and white. These poles serve as the perimeter markers of the kolong pigeon game arena and provide the anchor points for the ropes connected to both the upper and lower kolong. Each barrier pole has a cylindrical shape, with a diameter of 12 cm and a height of 9 m.

The findings documented in Table 2 demonstrate that the Kolong pigeon game, as a culturally embedded recreational practice, extensively operationalizes geometric mathematical concepts within its arena structure. Each arena component employs two-dimensional and three-dimensional geometric forms, encompassing concepts of symmetry, squares, rectangles, cubes, and cylinders. The utilization of these geometric forms provides essential structural support for the distinctive Kolong pigeon game arena configuration. Arena construction requires precise length, width, and height measurements for each component. This demonstrates that comprehension and application of geometric concepts fulfill essential roles in daily cultural activities (Sunzuma & Maharaj, 2022). Consequently, the Kolong pigeon game arena can serve as an authentic pedagogical context for mathematics instruction, thereby facilitating student understanding that mathematics provides substantive utility in everyday life. Through such game-based contexts, students engage not merely in mathematical learning but develop understanding of their environmental and cultural contexts (Wahyuni & Pratiwi, 2023).

These findings align with existing scholarship documenting widespread utilization of geometric concepts in cultural games. For example, Amsikan et al. (2023) demonstrated that the Kaneka and Mariam games operationalize three-dimensional geometric forms including spheres and cylinders. Similarly, Deda and Disnawati (2024) identified two-dimensional and three-dimensional geometric concepts in multiple cultural games including Galah Asin, Kelereng, Siki Doka, and Congklak.

The present findings further substantiate that geometric concepts are pervasively employed by communities in daily activities, both consciously and unconsciously. Geometric concept utilization extends across cultural game activities and diverse aspects of community life. This pattern is evidenced by multiple research findings: Darmayasa et al. (2023) documented geometric concept utilization by the Dayak Kenyah community in producing Bening and Woven cultural artifacts. Ahmad et al. (2024) identified geometric concepts in traditional ceremonial processions, specifically the Mappacci ceremony practiced by the Bugis ethnic group. Geometric concepts are similarly operationalized in gamelan musical instruments, mosque architectural design, and batik pattern composition (Ainora & Utami, 2024; Mellawaty et al., 2023; Permita et al., 2022).

Gameplay Rules, Procedural Steps, and Embedded Mathematical Concepts

The Kolong pigeon game operates according to fundamental regulatory principles that must be uniformly observed. These foundational regulations apply to all Kolong pigeon game activities and competitive events, requiring adherence by all practitioners and participants. Fundamental gameplay regulations were established through participant interviews, as illustrated in the following exchange:

> *Researcher: "What are the fundamental regulatory principles of the Kolong pigeon game?"*

Practitioner: "The fundamental regulation stipulates that pigeons must descend through the superior kolong and inferior kolong spatial boundaries when landing in the designated landing area. The pigeon achieving the most precise and rapid landing is determined the winner."
Researcher: "What occurs if a pigeon lands but fails to traverse the superior kolong and inferior kolong boundaries?"
Practitioner: "The landing is deemed invalid, and the pigeon is adjudicated as defeated."
The interview data establish that the Kolong pigeon game operates according to a fundamental regulatory principle: pigeons must achieve rapid and accurate landing trajectories traversing both the superior and inferior kolong boundaries. Additional interview, observational, and documentary data reveal that gameplay is conducted through team configurations consisting minimally of a pigeon releaser and a pigeon controller. The competitive mechanism pairs two teams in each match. The victorious team advances to subsequent competitive rounds. In the event of equivalent performance, both teams advance collectively to the next round.

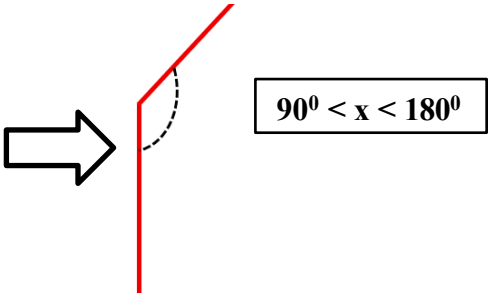
The Kolong pigeon game procedural sequence can be systematically categorized into three distinct stages: the waiting stage, the signaling stage, and the landing stage. Each stage incorporates specific regulatory requirements that must be observed. Each stage additionally operationalizes mathematical concepts, as systematically documented in Table 3.

Table 3. Mathematical Concepts Embedded in Kolong Pigeon Game Procedural Steps

The Stages of Kolong Pigeon Game

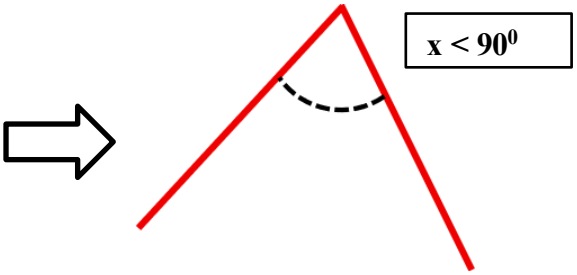

Waiting Stage

At this stage, the male pigeon is flown by a teammate serving as the pigeon flyer, from a distance of 1 km from the game arena. Meanwhile, the teammate acting as the pigeon controller holds the female pigeon and waits inside the bottom kolong area. During this waiting period, the pigeon controller must remain within the bottom kolong area, holding the female pigeon behind the body. The controller is not permitted to flap the female pigeon until the referee signals with a whistle. The player's body position during this stage follows the concept of an acute angle an angle less than 90° which is formed by the positioning of the hands behind the upright body.



Flapping Stage

In this stage, once the male pigeon is visible and the referee has blown the whistle, the pigeon controller may begin flapping the female pigeon to attract the male pigeon into the upper kolong. During this process, the controller must remain within the bottom kolong area in a standing position. The hands should be positioned above the head while holding the female pigeon securely, ensuring that it does not detach from the handle. The body position at this stage reflects the concept of an obtuse angle an angle greater than 90° but less than 180° formed by the hands pointing upward while the body remains upright.



Landing Stage

At this stage, when the male pigeon has entered the upper kolong area, the pigeon controller executes movement maneuvers by squatting while continuing to hold and flap the female pigeon. The objective is to guide the male pigeon to land accurately in the bottom kolong area. A landing outside this area is considered invalid, and the pigeon is deemed defeated. Contact with the boundary of the bottom kolong area is still considered a legal landing. The pigeon that lands the fastest and most accurately is declared the winner. The player's body position at this stage also follows the concept of an acute angle less than 90° which is observed from the position of the hands pointing downward while the body is in a squatting posture.

The findings documented in Table 3 demonstrate that the regulatory framework and procedural steps of the Kolong pigeon game operationalize angular geometric concepts. The specific angular concepts employed include acute angles and obtuse angles. Angular concept utilization is implemented through stage-specific gameplay regulations governing arm positioning and body postures that must be uniformly observed by all participants. This demonstrates that mathematical concepts are embedded within human kinesthetic and movement activities. Consistent with these findings, angular concepts are similarly employed

in traditional dance movements (Candrasari et al., 2023; Sulistyawati et al., 2025). Dance positional configurations can serve as authentic contexts for mathematics instruction (Wardah et al., 2023). Consequently, the kinesthetic positions employed in the Kolong pigeon game can be pedagogically utilized by integrating them as authentic contexts for angular concept instruction. The movement positions in the Kolong pigeon game can provide visual illustrations of angular forms, facilitating student comprehension of angular concept applications in their surrounding environment. Integrating mathematics instruction with authentic real-world contexts can enhance student interest and creative engagement during mathematical learning (Lestari et al., 2024).

Comprehensively, the exploratory findings of this investigation enrich ethnomathematical scholarship focused on cultural games. Additionally, these exploratory findings provide pedagogically applicable resources for mathematics educators, particularly for instruction addressing geometric forms and angular concepts. Mathematics and ethnomathematics possess substantial potential for integrated implementation to facilitate meaningful learning experiences (Rodríguez-Nieto et al., 2025). Educator awareness of culturally situated contexts amenable to geometric instruction integration can promote student comprehension of geometric concepts while simultaneously developing understanding of local cultural practices and environmental contexts (Sunzuma & Maharaj, 2021). Instructional approaches grounded in cultural games identified through ethnomathematical exploration can enhance student learning outcomes (Yumiati et al., 2023). Cultural game contexts can additionally serve to increase student interest in learning and improve the quality of mathematics instruction (Aras & Zahrawati, 2021; Arisetyawan et al., 2025).

Multiple instructional strategies can be implemented by mathematics educators utilizing the ethnomathematical exploration of the Kolong pigeon game as an authentic pedagogical context. For three-dimensional geometric form instruction, educators can employ the Kolong pigeon game arena structure as an authentic contextual reference. For two-dimensional geometric form instruction, educators can utilize the structural components of the Kolong pigeon game arena, which can additionally facilitate instruction addressing two-dimensional area measurement. Furthermore, participant positional regulations can be employed to provide concrete visual representations of angular forms. Through such integrative instructional approaches, students can engage with geometric and angular concepts in culturally contextualized frameworks while developing appreciation for local cultural practices. Ultimately, this investigation demonstrates that cultural games practiced within communities can serve as valuable pedagogical resources for mathematics instruction.

Conclusion

This ethnomathematical investigation explored mathematical concepts embedded within the Kolong pigeon game, a culturally significant competitive practice in Indonesian communities. The findings demonstrate that this cultural game extensively operationalizes geometric and angular mathematical concepts within its structural and procedural dimensions. Geometric

concepts are manifested within the game arena architecture, encompassing two-dimensional and three-dimensional forms including reflective symmetry, square configurations, rectangular forms, cubic structures, and cylindrical shapes. These elements provide essential structural foundations for arena construction and component design. Angular concepts are operationalized within the regulatory framework governing participant body positioning. Specifically, acute angles (less than 90°) and obtuse angles (greater than 90° but less than 180°) are embedded within positional requirements for different procedural stages. This finding illustrates that mathematical concepts extend beyond static structures to encompass dynamic kinesthetic activities within cultural practices.

These ethnomathematical findings offer significant pedagogical implications. The results can serve as authentic instructional resources for mathematics educators integrating culturally contextualized content into geometry and angular concept instruction. Such integration has the potential to facilitate more meaningful mathematics learning experiences demonstrating relevance to students' daily lives and cultural environments while fostering cultural appreciation. Finally, this investigation focused exclusively on identifying mathematical concepts embedded within the Kolong pigeon game. Future research should examine practical applications, including development of instructional materials, implementation of culturally integrated mathematics curricula, and empirical evaluation of student learning outcomes. Such investigations would provide comprehensive understanding of ethnomathematical integration efficacy in mathematics education.

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Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been covered completely by the authors.

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