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Exploring Mathematical Concepts in *Pèsapèyan Ling-Giling*: A Traditional Game as Miniature of Bull Racing in Madura Island

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Abstract. *Pèsapèyan ling-giling* was one of the iconic local wisdom of Madura. This game was a miniature version of the bull race. In this game, wheels replaced the bull as the driving force. As a result, this game was suitable for players of all ages. This research aimed to explore mathematical concepts in the *pèsapèyan ling-giling* game. This research used a qualitative approach with an ethnographic research type. Researchers used taxonomic analysis to examine the internal structure of mathematical concepts within the stages of the *pèsapèyan ling-giling* game. The study showed that the *pèsapèyan ling-giling* game contained mathematical concepts in the stage of tool-making, game rules, gameplay, and playing field. The mathematical concepts found in *pèsapèyan ling-giling* were numbers (e.g. the concepts of order, ranking, estimation, and optimization), measurement (e.g. the concept of length, area, speed, and distance, geometry (e.g. the concepts of lines, rectangles, circles, blocks, symmetry, coordinates, and position), discrete mathematics (e.g. the concept of graphs, relations and functions, and combinatorics) proportion, and probability. Thus, the traditional game of *pèsapèyan ling-giling* could be a learning medium for these mathematical concepts at elementary and secondary schools.

Keywords: Ethnomathematics; Local Wisdom of Madura; Mathematical Concepts; *Pèsapèyan Ling-Giling*; Traditional Games

Abstrak. *Pèsapèyan ling-giling* merupakan salah satu kearifan lokal Madura yang ikonik. Permainan ini merupakan miniatur dari karapan sapi. Peran sapi sebagai motor penggerak, dalam permainan ini diganti dengan roda. Sehingga permainan ini dapat dimainkan oleh segala usia. Penelitian ini bertujuan untuk mengeksplorasi konsep matematika dalam permainan *pèsapèyan ling-giling*. Penelitian ini menggunakan pendekatan kualitatif dengan jenis penelitian etnografi. Pengupulan data dilakukan dengan observasi, wawancara, dan dokumentasi. Peneliti menggunakan analisis taksonomi untuk memeriksa struktur internal konsep matematika pada tiap tahap permainan *pèsapèyan ling-giling*. Hasil penelitian menunjukkan bahwa permainan pèsapèyan ling-giling memuat konsep matematika pada tahap pembuatan alat, peraturan permainan, proses permainan, dan medan permainan. Adapun konsep matematika yang ditemukan dalam *pèsapèyan ling-giling* yaitu bilangan (konsep urutan, ranking, estimasi, dan optimasi), pengukuran (konsep panjang, luas, kecepatan dan jarak), geometri (konsep garis, persegi panjang, lingkaran, balok, simetri, koordinat dan posisi), matematika diskrit (konsep graf, relasi dan fungsi, serta kombinatorika), proporsi, dan probabilitas. Dengan demikian, permainan tradisional *pèsapèyan ling-giling* dapat dijadikan sebagai media dalam membelajarkan konsep matematika tersebut pada sekolah dasar dan menengah.

Kata kunci: Etnomatematika; Kearifan Lokal Madura; Konsep Matematika; *Pèsapèyan Ling-Giling*; Permainan Tradisional

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INTRODUCTION

Mathematics education can significantly benefit from being connected to contextual problems that incorporate cultural elements. Culturally relevant mathematics instruction fosters engagement and understanding by relating mathematical concepts to students' experiences (Acharya et al., 2021; Nur et al., 2020). For instance, the National Council of Teachers of Mathematics emphasizes the importance of shared conversations among educators and communities to create meaningful learning experiences. According to Ambrosio (1985), culture shapes how individuals think about and engage with mathematical practices, highlighting the need for mathematics education to reflect diverse cultural contexts. Furthermore, Desai et al. (2022) argue that more than merely including surface-level cultural activities is required; educators must intentionally bridge the intersection of culture and mathematics to value students' diverse identities as assets in the learning process. This approach enhances students' mathematical understanding and promotes a more inclusive and culturally conscious educational environment.

Mathematical concepts within a culture can be observed in local languages, traditional ceremonies, traditional architecture, dance art, music, song lyrics, traditional clothing, *batik* patterns, handicrafts, and traditional games (Johnson, 2017; Suherman, 2018; Turmudi et al., 2021). Research related to mathematical concepts in culture has been conducted throughout various regions of Indonesia. Ethnomathematical studies on traditional games have been conducted extensively. Among them are studies on the traditional marbles game (*kelereng*) (Febriyanti et al., 2018; Mei et al., 2020; Pratiwi & Heni, 2020; Uskono et al., 2023). In the marble game, concepts of distance, addition, and plane figures have been identified (Mei et al., 2020). The marble game involves three-dimensional shapes such as spheres, plane figures like circles and triangles, and concepts of distance and algebraic operations (Uskono et al., 2023). The marbles game also includes counting concepts (Febriyanti et al., 2019). Additionally, the marbles game has three-dimensional shapes like spheres, plane figures such as circles and triangles, and the concept of distance (Pratiwi & Heni, 2020). Furthermore, explorations have also been conducted on the *engklek* game. In the engklek and top-spinning games, concepts of squares, rectangles, semicircles, cylinders, and counting have been found (Febriyanti et al., 2018). The *engklek* game from Bondowoso has revealed concepts of counting, plane figures, nets, congruence, reflection, probability, and logic (Aprilia et al., 2019). Additionally, plane figure concepts have also been discovered in the *engklek* game (Priyanto et al., 2022).

Furthermore, in the traditional game of *congkak*, concepts such as rectangles, reflection, arithmetic operations, and number patterns were identified (Taus et al., 2022). The *bekles* game from West Java contained concepts of numbers 1-10, modulo, spheres, and probability (Hendriawan & Faridah, 2022). The traditional children's games from Makassar revealed geometric concepts (Muslimin & Rahim, 2021). The traditional game of *gatrik* involved geometric concepts, odd and

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even numbers, and division methods (Handayani & Irawan, 2021). In the traditional games *nasi goreng kecap* and *mejikuhibiniu*, number pattern concepts were discovered (Ramadhina et al., 2021). The traditional lore game included concepts of plane figures such as squares, rectangles, trapezoids, and circles (Cesaria et al., 2022). In the traditional game *pacu jalur*, the geometric concept of cylinders was found (Fendrikfendrik et al., 2020). The *dengklaq* game revealed concepts of plane geometry, angle relationships, cube nets, reflection, logic, and probability (Fauzi & Lu'luilmaknun, 2019). Finally, in the kite-flying game (*layangan*), plane figure concepts were identified (Kuswidi et al., 2021).

Several traditional games from Lampung province, such as *ketekhan, bedil betung, bedil locok, arul, min sundul khulah, bledukan*, and *taplak*, contain mathematical concepts such as numbers, geometric shapes, probability, distance, and speed (Merliza, 2021). The traditional game of marbles and *patok lele* from Nangapandan, NTT, contains the concepts of the ball, half ball, distance, addition, cylinder, comparison and multiplication (Amsikan & Deda, 2023). The traditional game *tong-tong galitong ji* from Malang, East Java, contains the concepts of addition, subtraction, multiplication, arithmetic operations modulo six and modulo three, arithmetic sequences, and probability (Turmudi et al., 2021). The traditional games from Kaliwungu, namely *tibrok, lumbungan, nekeran*, and *bekelan*, are found in the concepts of squares, rectangles, arithmetic operations, number sequences, circles, integers, arithmetic operations (Asriyani & Setyadi, 2023).

Madura, or what is often called the Salt Island, is one of the tribes and islands in East Java. As part of Indonesia, Madura is also rich in tradition and culture. *Kerrabhân sapè* is one of the iconic local wisdom in Madura. This local wisdom gave birth to a new culture called the *pèsapèyan ling-giling* game. This game, which is often called *kalèlès*, is a simplified version that replaces the function of the cow with a wheel so that it can be played anywhere by all groups and all ages. Studying mathematical concepts in the miniature cow racing game is essential and exciting. The game is indicated to contain mathematical concepts, but on the other hand, in previous research, no ethnomathematics studies have been found on the *pèsapèyan ling-giling* game. The mathematical concepts in traditional games in Madura that have been explored are the *loteng* game (Dhofir et al., 2019), the *kempreng* game (Susanti, 2020), the traditional game *bhisek/engklek, rem-ngerreman, bal-bleken, dakon, gobak sodor, lajengan, ba'-temba'an*, and *leker* have been studied (Zayyadi et al., 2018). Thus, this research aims to fill that gap by analyzing the mathematical structure of the *pèsapèyan ling-giling* game. Hopefully, this study can be a source of development for contextual learning in schools.

METHODS

This research uses a qualitative approach with an ethnographic type of research (Johansson, 2010;

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Wijaya, 2018). This research has two stages. The first stage was carrying out data mining related to the *pèsapèyanling-giling* game. Data mining at this stage is done through observation, in-depth interviews, and documentation in photos and videos regarding the culture of the *pèsapèyanling-giling* game. The instruments used in this research are observation sheets and interview question guidelines. The data collection process begins with conducting interviews and observations and taking documentation, such as photos or videos of the *pèsapèyanling-giling* game players. After that, in-depth unstructured interviews were conducted to collect information regarding the terms used in the game. The second stage explores mathematical concepts in the data obtained in the first stage.

The object of this research is the *pèsapèyan ling-giling* game and everything related to it. The research objects for the *pèsapèyanling-giling* game are as follows: a) The materials needed to make the game tools. b) Making game equipment. c) Supporting tools or materials (other than the leading playing equipment) needed to play. d) Rules in the game. e) Game process (describes the game steps in detail). f) Terrain or circuit for playing. The observation instruments in this research can be seen in Table 1. This research analysed the data using taxonomic analysis to explore the mathematical concepts contained in each part and stage of the *pèsapèyanling-giling* game. Data triangulation in this research is technical triangulation and source triangulation. The technical triangulation was carried out using three data collection methods: observation, documentation and interviews. Meanwhile, source triangulation in this research carried out data collection through two or more *pèsapèyanling-giling* players or two groups of *pèsapèyanling-giling* players or more.

RESULTS AND DISCUSSION

Pèsapèyan Ling-Giling Game

Based on the results of interviews, the traditional game of *pèsapèyan ling-giling* originates from Madura. This game was popular in the 80s. In that era, it became a favourite game because it was contested. Some of them were contested while celebrating "*Agustusan*" (Indonesia Independent Day) in Madura. This traditional Madurese game of *pèsapèyan ling-giling* is a miniature of *kerrabhân sapè*. If the cow race or cow racing competition uses cows as the driving force, then in the game of *pèsapèyan ling-giling*, the role of the cow is replaced by sandals tied with rubber nipples.

The traditional game of *pesapèyan ling-giling* uses special playing equipment adapted from *kerrabhân sapè* or cow racing competitions in Madura. The primary materials needed to make the *pèsapèyan ling-giling* game tool consist of bamboo, sandals, rubber nipples and raffia rope. The tools needed to make the *pèsapèyan ling-giling* game tool are a knife, hammer, saw, matches (resin), cutter, ruler (optional), and compass (optional), as in Figure 1.

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Figure 1. Materials for Making the *Pèsapèyan Ling-Giling* Game Tool

Process of Making Pèsapèyan Ling-Giling Tools

Making the *pèsapèyan ling-giling* game tool begins with cutting the bamboo used. The length of the cut bamboo does not have a standard requirement, so it can be adjusted to the maker's wishes. Measuring the length of bamboo can be done intuitively or using measuring tools such as a ruler. After determining the desired length, the bamboo is cut using a saw, as in Figure 2.

Figure 2. Measuring, Cutting, and Burning Bamboo

The bamboo used as *kalèlès* can be up to 60 cm long. Meanwhile, two bamboo sticks, each 30 cm long, are used for the tail, which are shaped like skewers. Another bamboo stick, with a convex tip (there is a curve at the end) and a length of about 15 cm, is placed between the two tail bamboos. These sizes are not standard and can be adjusted as needed. After cutting the bamboo for *kalèlès*, the next step is to burn the bamboo. The purpose of this burning is to make the bamboo more easily curved or shaped into a convex or concave shape. Once the four pieces of bamboo are ready, the next step is to assemble them using flip-flops and tie them with raffia rope so that it becomes the body of the *pèsapèyan ling-giling* tool as in Figure 3. The body of the game tool is called *kalèlès*.

Figure 3. *Kalèlès* Circuit

The wheels for the *pesapèyan ling-giling* game tool are made from flip-flops. The wheel's shape is created by drawing a circle on the surface of the flip-flop, which can be done with the help of a compass or manually without tools. After the circle shape is marked, the flip-flops are cut using

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a heated cutter. After the wheel has been cut, a hole is made in the centre of the wheel to insert the rubber valve. Two holes are made in the centre of the wheel to insert two rubber valve blocks. The complete shape of the wheel can be seen in Figure 4.

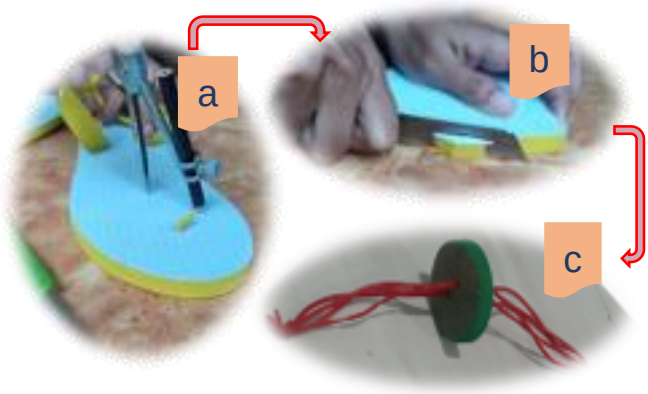

Figure 4. Making the Wheel

Once all the parts, including the set of bamboo pieces and the wheel, are ready, the final step is to assemble them into a complete *pèsapèyan ling-giling* tool. This tool is then ready to be used for playing. The final shape of the *pèsapèyan ling-giling* tool is shown in Figure 5.

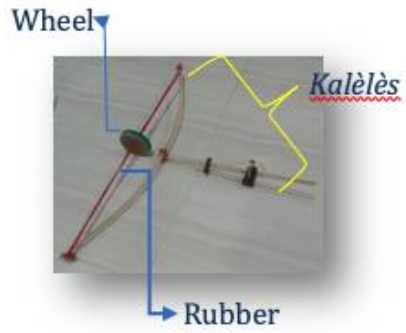

Figure 5. *Pèsapèyan* Ling-*Giling* Tool

Pèsapèyan Ling-Giling Game Rules

In the game of *pesapèyan ling-giling*, the rules applied are flexible and can change according to the players' agreement. However, in games that are usually played by children traditionally, not in the context of official competitions, there are general rules. This game is played individually, with three players competing in each round to determine the winner. Three new players will participate in each round, and one winner will be selected. This process continues until it reaches the quarter-finals and finals, and finally, a champion will be determined. The number of rounds and stages of the game depends on the number of participants participating. The winner in the *pesapèyan ling-gilling* game is determined by the player whose machine moves the fastest or reaches the finish line first.

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Game Process

The *pèsapèyan ling-giling* game begins with each player spinning the wheel of their tool until the rubber valve rolls up, as in Figure 6a. It is essential to pay attention to the direction of rotation of the wheel because if the wheel is turned outward, the tool will move backwards, whereas if it is turned inward, the tool will move forward. Therefore, the wheel's rotation determines the direction of movement of the rolling pin. The game begins once all three players have had enough spins on their wheels. The players prepare at the starting line, as shown in Figure 6b. When the signal to start was given, they released their *pesapèyan ling-giling* tools. This moment was exciting because the machines were moving along varying trajectories; some were moving backwards and sideways, and some were moving straight at high speed. The fun created by playing with friends like this is unique and different from playing with gadgets.

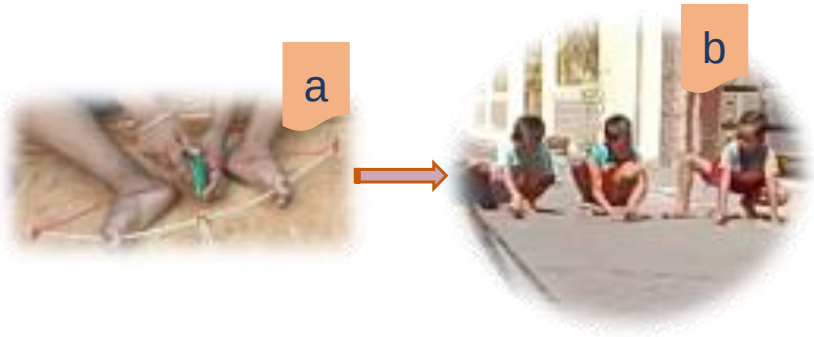

Figure 6. Making a Rubber Twist on the Tool and Playing it

Playing Field

No special provisions exist regarding the terrain used to play the traditional game of *pèsapèyan ling-giling*. Kids can play anywhere. However, children generally choose flat terrain, as shown in Figure 7, to play with a wide field sufficient for a maximum of 3 players. If the terrain is not solid, such as sandy terrain, then the *kalèlès* wheels can be serrated.

Figure 7. Playing *Pèsapèyan Ling-Giling* on Flat Terrain

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Mathematical Concepts in the Process of Making the *Pèsapèyan Ling-Giling* Tool

Measurement

Measuring the length of bamboo using a ruler or intuitively (sense) involves the concept of measuring length. Even though the measurements used are not always standard, there are still relative measurements to determine the length of the piece, as shown in Figure 8a. NCTM, 2000, p. 44, states, "measurement is the assignment of a numerical value to an attribute of an object, such as the length of a pencil" (Jones, 2012, p. 404). When cutting a circle on a flip-flop to make a wheel, the concept of the circle's diameter is also involved, especially in ensuring that the wheel being made is of the appropriate size, as in Figure 8b.

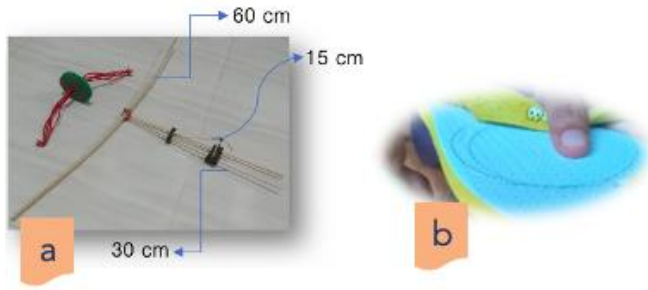

Figure 8. Measurement Concept

Geometry

"A circle is the set of all points in a plane that are at a given distance from a particular point (known as the centre of the circle)" (Alexander & Koeberlein, 2015, p. 15). In line with this definition, making a wheel from flip-flops involves the concept of a circle, including drawing a circle and determining the radius of the circle. The centre circle concept is also applied when perforating the wheel's centre point to insert the rubber valve. Making the connecting bearing on the kalèlès' tail involves a rectangle or cuboids with two different sizes on each tool, as in Figure 9a. Forming bamboo to become convex or concave after burning involves understanding the basic geometric shapes, as in Figure 9b.

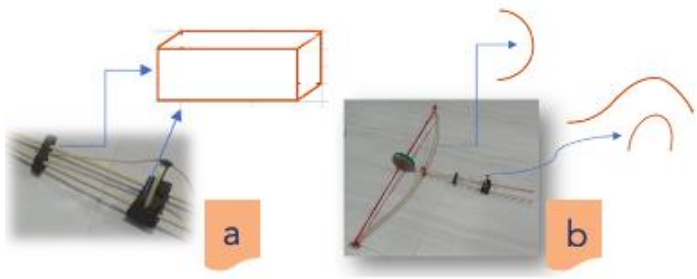

Figure 9. Geometry Concept

Symmetry is applied when placing two bamboo as identical tails on either side of a convex bamboo. This symmetry is essential to ensure the balance of the game tool when used. Alexander &

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Koeberlein. Alexander & Koeberlein (2015, p. 103) define symmetry as follows, "A figure has symmetry with respect to a line l if for every point X on the figure, there is a second point Y on the figure for which l is the perpendicular bisector of $\overline{XY}$."

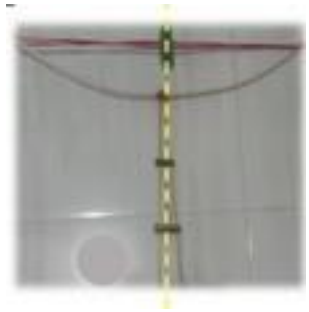

Figure 10. Symmetry Concept

Determining the wheel's centre point to make a hole in the centre involves the concept of a central position in circular coordinates, as shown in Figure 11.

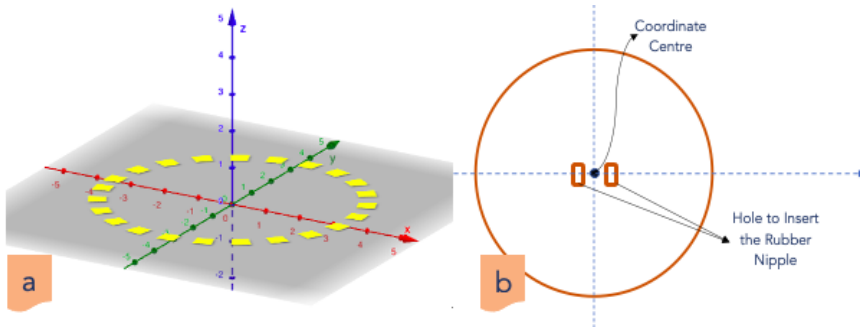

Figure 11. Concept of Coordinates and Position

Proportion and Scale

The proportion of length between the kalèlès and the tail reflects an understanding of proportion and balance, which is essential to ensure the playing instrument can function correctly. Although sizes are not standard, there is a relative scale between the lengths of bamboo for kalèlès and tails and between the sizes of wheels and strings of bamboo.

Jones (2012, p. 329) defines proportion as follows, "A proportion represents a relationship between two equivalent ratios, which can also be viewed as equivalent fractions." For example, the proportion of kalèlès (main long bamboo) with twin-tail bamboo is 60:30 = 2:1. The proportion of twin-tail bamboo with a short tail in the middle is 30:15 = 2:1. Meanwhile, the proportion between kalèlès (main long bamboo) with twin tail bamboo with a short tail in the middle, namely 60:15 = 4:1. However, please note that this proportion is not an absolute proportion. Toolmakers and ling-mill players can experiment to find the most ideal proportions.

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Estimation

Cutting bamboo and making wheels oft involves estimation, mainly if precise measuring tools are not used. Estimation helps in estimating the appropriate length of bamboo or wheel circle shape. "Estimation is a skill that is used in everyday life" (Jones, 2012, p. 410). According to Jones (2012, p. 267), estimation is usually performed mentally and quickly. Sometimes, estimates are more useful and more efficient than exact calculations.

Mathematical Concepts in the Rules of the *Pèsapèyan* Ling-*Giling* Game

Probability and Combinations

In this game, there is an element of probability regarding each player's chance of winning in a particular round. With various rounds involving different combinations of players, a combination analysis can be used to calculate the probability of various outcomes from each round until the final. It is under the definition of probability stated by Jones (2012, p. 453): "Probability is closely related to data analysis. It is a measurement of the likelihood of an event."

Suppose there are six players. Each player's chance of winning can be calculated using odds theory. In the first round, two groups were formed with three players each. So that each player has the following chance of winning in each group:

$$\mathrm{P(A)} = \frac{1}{3}.$$

In the second round, two participants will play so that each participant in the second round has the following opportunities.

$$\mathrm{P(A)} = \frac{1}{2}.$$

Thus, the opportunity for each player to become the game's champion can be formulated as follows.

$$\mathrm{P(A)} = \frac{1}{3} \times \frac{1}{2} = \frac{1}{6}.$$

Order, Comparison and Ranking

Players are ranked based on speed or order of reaching the finish line. It involves the concept of ordering and ranking, where the winner of each heat is determined by whose *kalèlès* are faster or farther. Even in everyday game practice, children use their sense of sight to determine whose *kalèlès* game tools are faster. However, this process implicitly contains the concept of number ordering (ordering relationships).

For example, there are three participants in the game, namely A, B, and C. Imagine that there are judges who use a stopwatch to calculate the time each playing equipment takes. So that the

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numbers can be sorted based on the speed data obtained, they are comparing the time or distance travelled by players' equipment. In this activity, there is a process of comparing numbers to obtain a sequence and ranking.

Discrete Mathematics

The selection of players who qualify for the next stage after the initial round involves discrete mathematical concepts primarily related to the game structure, which consists of elimination rounds. This process includes repeated selection and elimination of players until a final champion is determined. In the game of *pèsapèyan ling-giling*, discrete mathematics concepts can be applied to select and eliminate players during the game, especially in tournament structures involving elimination rounds. The following are examples of discrete mathematics concepts that can be identified in this game.

Directed Graphs and Trees

In games with an elimination system, players who pass or are eliminated can be represented using a directed graph. Each vertex (node) in the graph can represent a player, and the arc (edge) shows the result of a match or challenge between two players. After each game or challenge, the winner moves to the next node along the graph, while the loser drops out of the competition. Ultimately, this graph forms a tree where only one player reaches the top (root) of the tree, becoming the final winner. Directed graphs and trees This whole process can be visualized with a directed graph, where each node represents a player, and the arc shows the outcome of the match, with the final winner as the root of the tree formed, as in Figure 12.

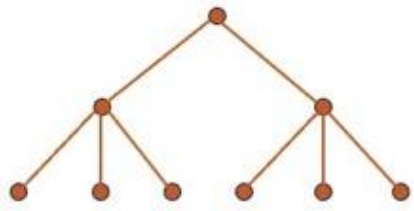

Figure 12. Graph Concept

Relations and Functions

Each round in the game is a relationship between two sets of players: the set of players participating at the start of the round and the set of players who advance to the next round. If each match produces one winner, this relationship is a function that maps each player taking part in the match to the players who advance to the next round. This function helps determine who advances to the next round based on the game results, as shown in Figure 13.

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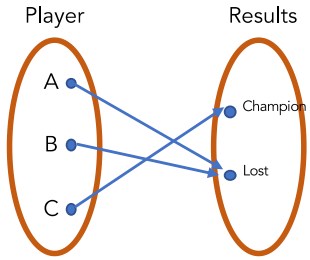

Figure 13. Concept of Relationship and Function

Combinatorics

Combinatorics can be applied to calculate the number of ways players can be paired for a match in each round. For example, if there are six players, determining the number of combinations to form 2 groups of 6 participants can be done as follows.

Select three people from 6 people for the first group. The number of ways to select three people from 6 is as follows.

$$C_3^6 = \frac{6!}{(6-3)!3!} = \frac{6\times5\times4}{3\times2\times1} = 20.$$

Because the division of two groups does not pay attention to order (groups A and B are the same as groups B and A), the results of the combination need to be divided by 2.

$$\text{Number of Ways} = \frac{20}{2} = 10.$$

So, the number of ways to form these two groups is as follows.

Speed and Distance

Determining the winner based on the speed of the vehicle and the distance traveled to the finish line includes basic physics concepts that are closely related to mathematics, namely speed as a function of time and distance.

Iteration and Patterns

Games played in several rounds until the final show a pattern of repetition and iteration, where the same process is repeated with different players until the final stage is reached. It is under the meaning of iteration conveyed by Jones (2012, p. 492): "Iteration means repeating something over and over."

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Mathematical Concepts in the *Pèsapèyan Ling-Giling* Game Process

Rotation and Circular Motion

Turning the wheel until the rubber valve is rolled involves the concept of rotation and circular motion. The direction of rotation that determines forward or backward movement is an example of applying the principle of rotation in everyday life, as shown in Figure 14a.

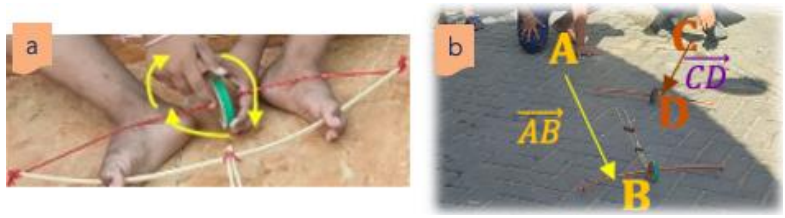

Figure 14. Rotation and Vector Concepts

The variability of the tool's trajectory after release, as in Figure 14b, shows variations in the tool's response to uniform initial conditions (i.e., equally rotated by the player). It reflects the concept of variability in statistics or probability theory. One of the causes of non-straight motion or speed in a rolling mill tool is that it is caused by an imbalance in the tool being made. Mathematics calls this "non-symmetry."

Vectors and Direction

Determining the direction of movement of the tool based on the direction of rotation of the wheel reflects the use of vector concepts in mathematics, where the direction and magnitude of rotation influence the final result, namely the direction of movement of the tool. In traditional games such as pèsapèyan ling-giling, which involves the rotation of a wheel and the twisting of a rubber valve, the vector concept can be illustrated through the direction of rotation of the wheel and the resulting rubber twisting. The following is an explanation of the vector concept in this context.

Rotation Vector

The spinning wheel in the game can be represented by a vector that shows the direction and magnitude of the rotation. Suppose the wheel rotates clockwise. The direction of the rotation vector can be expressed in a specific direction, such as to the right when viewed from above. If the wheel rotates counterclockwise, the rotation vector will point in the opposite direction (to the left).

Vector Coil

The coil of rubber valve formed from the wheel's rotation can also be described as a vector. If the rubber valve is wound in the same direction as the wheel rotation (clockwise), the winding vector will have the same direction as the rotation vector. If the rubber valve is wound in the opposite

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direction from the rotation of the wheel, then the winding vector will be in the opposite direction from the rotation vector.

Suppose the wheel in the game rotates clockwise (to the right). The rubber valve wrapped around the wheel also follows the same direction, so the Rotation Vector points to the right (or under the direction of rotation of the wheel). The Winding Vector points to the right, too, because the winding follows the direction of wheel rotation. If the rubber valve is wound in the opposite direction to the wheel's rotation direction, then the Rotation Vector points to the right. The winding vector points to the left because the rubber winding is opposite the direction of wheel rotation.

Thus, in this game, the vector concept describes the direction and magnitude of the wheel rotation and the direction of the rubber valve winding. This vector helps us understand how the movements in the game are related to each other and influence the final result, such as the tension or flexibility of the formed rubber coil.

Lines and Positioning

The players line up straight at the starting line, which involves basic geometric concepts regarding lines and positions. It also shows the importance of the starting position of players and tools when starting the game, as in Figure 15. Therefore, it is not uncommon for some line or other to mark the starting position so that it becomes fair play.

Figure 15. Concept of Line and Position

Mathematical Concepts on the Playing Field of Pèsapèyan *ling-giling*

There are five mathematical concepts contained in the pèsapèyan ling-giling game field.

Geometry

The selection of flat terrain involves the concept of plane geometry, where a flat surface is considered ideal because it minimizes resistance and ensures that the rolling pin can move more stably and consistently.

Calculating or Estimating

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The concept of area in mathematics is involved when determining whether a chosen terrain is large enough to be used by a maximum of three players. It involves calculating or estimating the area needed so that each player has enough space to move without bumping into each other.

Scale and Proportion

Although there are no specific provisions, the appropriate field size for three players must be considered. It shows an understanding of scale and proportion in the context of terrain large or small enough for the number of players involved.

Optimization

Children intuitively optimize in choosing the most suitable terrain for playing. They consider terrain conditions that allow the game to run smoothly and fairly for all players, which is a simple form of the concept of optimization in mathematics.

Coordinates and Position

Although not explicitly stated, player placement within the selected terrain involves coordinates and position within an area. This concept relates to how players spread out on the field in a balanced position so that the game runs well.

The results of the research show that there are mathematical concepts in the game of *pèsapèyan ling-giling*. The process of making tools stages contain mathematical concepts, game measurements, geometry, proportion and scale, symmetry, estimate, coordinates and position, and function. The game's rules contain mathematical concepts, probability, combinatorics, sequence and ranking, graphs, relations and functions, speed and distance, and comparison. The game process contains mathematical concepts of rotation, vectors, lines, and positions. The playing field contains mathematical concepts, geometry, measurement (area), optimization, coordinates, and placement.

The research results indicate that the traditional game of pèsapèyan ling-giling is rich in mathematical concepts, providing a unique context for exploring various mathematical principles. Among them, the concepts of measurement (Zayyadi et al., 2018), number order (Asriyani & Setyadi, 2023), comparison (Amsikan & Deda, 2023), speed (Merliza, 2021), and opportunity (Aprilia et al., 2019). These concepts highlight the game's inherent mathematical nature and demonstrate how traditional games can be practical tools for teaching and learning mathematics. By engaging with these concepts in a familiar and enjoyable context, students can better understand mathematical principles and their applications in real-life situations.

In addition to the concepts above, this research uncovered geometric principles that resonate with earlier studies (Fendrikfendrik et al., 2020; Kuswidi et al., 2021; Merliza, 2021). However, it is noteworthy that previous research should have addressed the concepts of symmetry, coordinates, and

position identified in this study. Including these geometric concepts further enriches the mathematical framework associated with pèsapèyan ling-giling, suggesting that traditional games can be valuable for exploring a broader range of mathematical ideas.

Moreover, this research uniquely contributes to understanding discrete mathematics within the context of pèsapèyan ling-giling, revealing concepts such as graphs, relations, functions, and combinatorics that were not previously documented. The discovery of these discrete mathematics concepts emphasizes the potential of traditional games to introduce complex mathematical ideas in an accessible manner. Educators can foster a more comprehensive understanding of mathematics by integrating these concepts into the learning process, encouraging students to appreciate the connections between mathematical theory and practical applications in their cultural heritage. This approach enhances mathematical learning and promotes cultural awareness and appreciation among students.

Including mathematical concepts in the game of pesapèyan ling-giling has implications for learning media references. The game of *pesapèyan ling-giling* can be used as a learning media for mathematics learning. The concept of numbers, which includes the concepts of sequence, ranking, estimation, and optimization, can be taught at primary and secondary schools. The concept of measurement, which includes length, area, speed, and distance, can also be taught at primary and secondary schools. Meanwhile, probability, proportion, geometry, and discrete mathematics concepts can be taught at the secondary schools.

CONCLUSION

The traditional Madurese game pesapèyan ling-giling contains mathematical concepts in making tools, rules, processes, and playing fields. The mathematical concepts at the tool-making stage include measurement, geometry, proportion, symmetry, estimation, coordinates, and position. The game rules contain the concepts of probability and combination, sequence, ranking, discrete mathematics, speed, distance, iteration, and patterns. The game process contains the concepts of rotation, vectors, lines, and positions. The playing field contains the concepts of geometry, area, size, optimization, coordinates, and position. The concept of number and measurement in the game pèsapèyan ling-giling can be taught at elementary and secondary schools. Meanwhile, the concepts of geometry, proportion, probability, and discrete mathematics in the game pèsapèyan ling-giling can be taught at secondary schools.

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