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An inquiry into ethnomathematics within the framework of the traditional game of *Congklak*

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Abstract

Ethnomathematics represents a paradigm within mathematics education that centers on integrating and applying mathematical principles, concepts, and methodologies embedded within the cultural fabric of specific communities. Within the Indonesian cultural milieu, traditional games constitute a significant aspect. Hence, this study investigates the traditional game of *Congklak*, aiming to explicate its underlying modulo concept. Employing a qualitative research design grounded in ethnographic methodology, the investigation draws upon a multifaceted approach, including a literature review, documentation analysis, participant observation, and interviews with custodians of the *Congklak* tradition. Data validation is achieved through triangulation of sources and methods. Data analysis involves iterative data reduction, presentation, and inference drawing processes. Findings reveal the presence of a modulo concept within the traditional *Congklak* game, which governs the determination of the final seed distribution position. Furthermore, additional mathematical elements, notably addition operations, are identified. The identified modulo concept offers a compelling avenue for enriching mathematical pedagogy, particularly in the realm of modulo arithmetic operations, by providing an alternative cultural context for learning.

Keywords: ethnography, ethnomathematics, modulo, the traditional game of *Congklak*

Introduction

Traditional games embody the local wisdom born from communities' adaptation to environmental conditions, life requirements, and prevailing values and norms (Mawehe, 2015; Risdiyanti et al., 2019; Prahmana, 2022). *Congklak*, a traditional game rich in cultural and

historical significance, is recognized as an effective educational tool (Yantoro et al., 2021; Alvisari et al., 2023). Traditional games, like *Congklak*, captivate children's interest because they reflect activities from their everyday surroundings (Kurniawan et al., 2022). Research by Iswinarti and Suminar (2019) demonstrates that using traditional Javanese games in educational settings can enhance student engagement, promote active participation, stimulate problem-solving skills, and encourage effective learning strategies. However, as modernization progresses and societal perspectives shift, the cultural importance of traditional games like *Congklak* risks being neglected. Therefore, this study aims to explore the concept of ethnomathematics within the *Congklak* game, aiming to unearth the deeper educational and mathematical insights it offers, thereby reinforcing the value of preserving traditional games.

In many educational systems, the mathematics curriculum is often structured around standards that only sometimes consider the local cultural context, resulting in disengagement and a need for meaningful learning experiences for students (Nasir et al., 2008; Louie, 2017). This calls for innovative methods to improve mathematical skills by integrating cultural elements. Ethnomathematics, a specialized approach to mathematics education, connects mathematical concepts with local traditions and cultural practices, creating a more engaging and practical learning experience (Machaba & Dhlamini, 2021; D'Ambrosio & Rosa, 2017). Ethnomathematics thus emerges as an appealing method to improve students' understanding of mathematics (Rosa & Orey, 2021).

This study examines ethnomathematics within the traditional game of *Congklak*, where grains are distributed among holes on a board according to specific rules. The movements involved in playing *Congklak* promote various cognitive abilities, including problem-solving, strategic thinking, analysis, and estimation, which are crucial for cognitive development (Alvisari et al., 2023; Kurniawan et al., 2022). Consequently, this research aims to contribute to a more culturally contextualized approach to mathematics education and enrich mathematics teaching practices by integrating local cultural heritage.

By exploring the mathematical concepts within *Congklak*, particularly modulo, this study offers new insights into how mathematics is applied in local cultural contexts. It also aims to inform the development of a mathematics curriculum that is more culturally relevant while enriching our understanding of traditional cultural heritage. Educators can create more engaging learning strategies by understanding the relationship between conventional games and mathematical concepts (Hidayati & Prahmana, 2022; Qirom & Juandi, 2023).

Ultimately, this study contributes to the ongoing discourse on innovative educational methods by exploring the potential of traditional games in teaching mathematical concepts. By reintroducing traditional games like *Congklak* into educational contexts, educators can foster a deeper connection between students and their cultural heritage while simultaneously enhancing their mathematical skills. This research sets the stage for future studies exploring other traditional games and their educational applications, contributing to a more holistic and culturally inclusive approach to education.

Methods

This study adopts a qualitative research approach to explore games' cultural and mathematical aspects (Li & Tsai, 2013; Hung et al., 2018), such as the traditional game of *Congklak*. Qualitative research allows for an in-depth exploration of complex social phenomena through narrative data, such as words and images, collected from observations, interviews, and focus group discussions (Moser & Korstjens, 2018; Tracy, 2019; Pyo et al., 2023). This study employs an ethnographic approach to understand the cultural practices and sociocultural significance associated with the game. Ethnography is suitable as it examines social interactions and cultural traditions within their natural context (Siraj-Blatchford, 2010; Hockey, 2020; Silverman et al., 2021). By adopting this approach, this study aims to uncover the historical, philosophical, and mathematical aspects inherent in the traditional game *Congklak*.

Data for this study was collected through participant observation, in-depth interviews, and a literature review. Participant observation was conducted in settings where the traditional game *Congklak* is played to understand its cultural context. In-depth interviews were carried out with key informants who have deep knowledge of the game's history and significance, including Mr. Abbet Nugroho, manager and owner of "Kampoeng Dolanan Nusantara Borobudur," and Ms. Irma Ristiana, Project Manager of the "Pendidikan dan Mainan Kolong Tangga" Museum. These interviews aimed to collect information about the game's cultural value and historical background. The literature review involved gathering relevant secondary data to supplement the insights obtained from primary sources. This combined data collection approach ensured a comprehensive understanding of the topic.

The data analysis framework for this study consists of two main phases: pre-field analysis and in-field analysis. Pre-field analysis involved reviewing secondary data and existing literature to identify key themes and concepts relevant to the study's focus. This step helped to refine the research questions and establish a preliminary structure for data collection. The in-field analysis involved three key processes: data reduction, data presentation, and conclusion drawing. Data reduction consisted of coding and categorizing the collected data to identify recurring themes and patterns. Data presentation focused on organizing the coded data into coherent structures for interpretation—the conclusion drawing involved synthesizing the findings to derive meaningful insights and validate the research objectives.

Ethical considerations were central to the research process. Before data collection, informed consent was obtained from all participants, ensuring they understood the purpose of the study and their right to withdraw at any time. Confidentiality was maintained by anonymizing participant identities in the research report and storing sensitive information securely. The study adhered to ethical guidelines for qualitative research, and approval was obtained from the relevant institutional review board or ethics committee. Cultural sensitivity was a priority during the data collection process, ensuring respect for the participants' cultural practices and traditions.

The findings of this study will be structured to provide a clear and coherent narrative. The research report will contain sections describing the research methodology, the data collection process, and the analysis approach. The results section will integrate quotes, images, and other

qualitative data to support the findings. By presenting the data to reflect the participants' experiences, the study aims to convey the cultural and mathematical significance of the traditional game *Congklak*. The conclusion will summarize the key insights and discuss potential limitations, suggesting areas for further research to expand the understanding of this traditional game and its cultural impact.

Results and Discussion

This research explores the traditional game of *Congklak* in Indonesia. Although the traditional game of *Congklak* belongs to Indonesia, this game is not native to Indonesia. An illustration of this game can be seen in Figure 1.

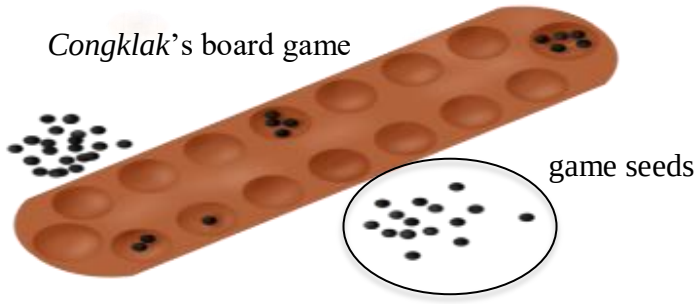

Figure 1. The Game Kit of *Congklak*

The origins of traditional games, particularly *Congklak*, are shrouded in ambiguity, with limited information on where these games initially emerged. Although traditional games in Indonesia are commonly considered local, many of them, like *Congklak*, likely have roots outside of the archipelago. *Congklak*, a traditional game often associated with Indonesia, is believed to have originated on the African continent around five to six thousand years ago, and it may have been introduced to Indonesia by colonizers or traders. Despite its foreign origins, *Congklak* has become integral to Indonesian culture. It was officially recognized as an intangible cultural heritage in DKI Jakarta in 2012 (Direktorat Warisan dan Diplomasi Budaya, 2012).

The game's widespread adoption across Indonesia has led to regional variations and different names. In Sumatra and Betawi, it's called *Congklak*, while in Java, it is called *Dakon*. Each name represents unique cultural elements and gameplay variations, adding to the rich tapestry of Indonesia's traditional games (Nurjatisari et al., 2023). The variations in names and playing styles reflect the diverse cultural history of Indonesia, but they also contribute to the uncertainty regarding the precise origins of *Congklak*.

Given the complexity and diversity of the game's history, pinpointing its exact roots remains challenging. What is clear, however, is that *Congklak* has evolved into a significant cultural artifact within Indonesia. It holds educational, social, and traditional values, serving as

a bridge between generations and a testament to the enduring nature of cultural exchange (Van, 2022; Prahmana et al., 2023).

Congklak, a traditional game played by two individuals, involves a *Congklak* board and seeds known as *Congklak* seeds (Alvisari et al., 2023). The board is typically made of wood, and the seeds are often derived from *sawo kecik* trees, though variations exist across regions (Yantoro et al., 2021). The board has an even number of holes, with each player having one large hole (referred to as the *lumbung*) and several smaller holes. The giant hole is positioned on the player's right side, while the smaller holes are arrayed in front of each player, constituting their property.

Before the game begins, each small hole is filled with an odd number of seeds, ensuring the holes contain the same amount. The game starts after determining who goes first, often through a quick game of rock-paper-scissors or a similar method. The first player chooses one of their holes, collects the seeds, and distributes them by placing one seed in each hole to their right, continuing in a counterclockwise pattern. If the seeds run out in a small hole with additional seeds, the player takes them and continues placing them until they reach their large hole or *lumbung*. The game ends when no more seeds are left to collect from the smaller holes, and the winner is the player who has accumulated the most seeds in their *lumbung*.

While *Congklak* boards were traditionally made of intricately carved wood, today, they are often produced from plastic and sold in toy stores, reflecting the evolving nature of the game. Despite these changes, *Congklak* holds significant educational and developmental value for children. Beyond providing entertainment, the game promotes critical thinking by encouraging players to strategize their moves for victory. The game's turn-based nature also helps children develop patience and emotional control while waiting for their turn to play. Thus, *Congklak* serves as a cherished traditional game and a tool for fostering personal growth and cognitive skills in younger generations.

In the traditional game of *Congklak*, a fascinating connection to mathematical concepts, particularly the concept of modulo, emerges through the gameplay. As players distribute seeds across the board's holes, they engage in a pattern of counting and redistribution that inherently involves modulo arithmetic. This concept becomes evident when players count the number of seeds that end up in their barn (*lumbung*) at the game's end and during the seeds' distribution as they play.

Researchers who have examined the game from a mathematical perspective have noted that the gameplay's counting and distribution mechanics can be understood through modulo arithmetic. In mathematical terms, modulo refers to the remainder after division by a specific number. This is applicable in *Congklak* as players circulate seeds around the board, where each completed loop resembles a modulo operation.

For example, during seed distribution, when players pick up seeds from a hole and distribute them across the board, they effectively engage in a modulo-based operation as they count out each seed. The process can be understood as distributing a set of seeds among a certain number of holes, with the modulo determining where the last seed will land. This cyclic distribution, often resulting in a remainder, aligns with the core principles of modulo arithmetic.

Exploration of these mathematical elements in *Congklak* has revealed that the game can practically demonstrate the concept of modulo and fundamental arithmetic (Susanti, 2020; Tusolihah et al., 2022; Irawan et al., 2023). As players count and distribute seeds, they intuitively understand these mathematical operations, showing how traditional games can be a valuable educational tool for reinforcing mathematical concepts. By integrating traditional games like *Congklak* into educational practices, educators can introduce mathematical concepts in an engaging and culturally relevant way.

The Concept of Modulo

In the traditional game of *Congklak*, the gameplay involves the strategic distribution of seeds into various small holes and the players' barns. Researchers exploring this game have noted that players must calculate their steps as they move seeds from one hole to another, effectively creating a cyclical pattern. This pattern involves using modulo arithmetic to determine where the last seed will land after a distribution cycle. The modulo operation plays a crucial role in the game's strategy, allowing players to predict the position of the last seed and plan their moves accordingly (Alvisari et al., 2023; Irawan et al., 2023).

To illustrate, consider a scenario where a player takes seeds from a particular hole and then distributes them in a sequence (Yantoro et al., 2021). The distribution includes the small holes leading toward the player's barn. The number of steps, and thus the pattern of seed distribution, depends on the number of seeds picked and the number of holes in play. Modulo arithmetic helps the player calculate where the final seed will end after a complete cycle of distribution. This can significantly impact the game's outcome, influencing the player's strategic decisions regarding which holes to target and how to maximize seed collection.

The modulo concept in *Congklak* follows standard arithmetic principles, where the modulo of a division operation is the remainder when one number is divided by another (Prahmana et al., 2021). By applying this concept, players can determine the cyclical pattern of seed distribution, directly affecting gameplay strategy. Predicting where the last seed will land is a valuable skill, guiding players to make optimal moves to gain an advantage (Tusolihah et al., 2022). This strategic element demonstrates how traditional games like *Congklak* can inherently teach mathematical concepts, showing the practical applications of modulo in a culturally engaging context.

For example, we give n as the number of holes on each side of the *Congklak* board, L_s as the initial hole where the player takes the seeds, B as the number of seeds taken from the initial hole, and L_e as the hole where the player has to put the last seed after scattering seeds from the initial hole. The formula to determine L_e is as follows,

$$L_e = (L_s + \mathrm{B} - 1)\ mod\ n$$

The steps to determine the L_e hole with modulo operation are as follows,

1. Add the number of seeds taken (B) to the initial hole (L_s)

2. Subtract one (1) from the results of the addition operation before because the last seed taken must be placed in the last hole after spreading the seeds
3. Modulo operation with n (number of holes) determines the hole to be filled with the last seed. This ensures that the retrieved seeds are evenly distributed to all holes, including the skipped holes.

So, the formula $L_e = (L_s + \mathrm{B} - 1)\ mod\ n$ uses modulo operation to determine the hole to be filled with the seeds taken from the initial hole in the game of *Congklak*.

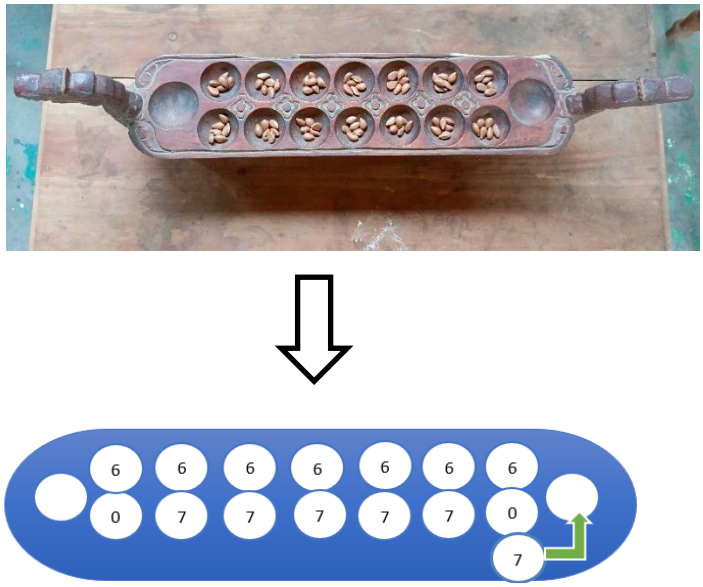

Figure 2. The result of the Modulo operation on the *Congklak* game

Figure 2 depicts the game of *Congklak*, illustrating how the distribution of seeds incorporates a modulo operation. This operation helps determine the placement of the seeds during gameplay and is used to anticipate the end position of the last seed taken during a turn. The following game rules outline how this modulo operation can be applied in the game of *Congklak*:

1. Initial Setup: Each player has a sizeable *lumbung* hole, which serves as a storage area for collected seeds. Additionally, each small hole on the *Congklak* board is filled with equal seeds before the game begins, while the *lumbung* remains empty.
2. Starting Conditions: The seeds must only be placed in the smaller holes, leaving the *lumbung* unfilled. This setup ensures each hole contains a consistent number of seeds.
3. Determining the First Player: The player who plays first is usually determined through a simple suit, such as rock-paper-scissors.
4. Seed Distribution: The active player selects one of the small holes from their side of the board, collects all the seeds, and distributes them clockwise among the subsequent holes, including their *lumbung* if they pass it. This distribution pattern is the point where the

modulo operation is applied, especially to anticipate the final position of the last seed in the distribution cycle.

5. Continuing Play: If the last seed from the distribution lands in a hole containing other seeds, the player continues spreading the seeds from that point. This process continues until the last seed lands in an empty hole.
6. Shoot or 'Eat' System: If the last seed falls into an empty small hole on the player's side, and the hole opposite it (belonging to the opponent) is filled with seeds, the player can capture all the seeds from the opposite hole as part of the shoot or 'eat' system.
7. Applying Modulo: The modulo concept can be used to determine the last position of the seed from a player's chosen starting point. It can predict where the seed will land after a complete distribution cycle, guiding the player's strategy. However, it should be noted that the modulo concept determines the final position of the last seed taken during the turn rather than predicting the subsequent redistribution when the last seed falls into a filled hole.

This set of rules and the use of modulo arithmetic provide a unique insight into the game's strategy, showcasing how traditional games like *Congklak* can incorporate mathematical principles to enhance gameplay while simultaneously serving as educational tools.

Addition Operation

As explained earlier, in the game of *Congklak*, addition is used in several contexts, especially in calculating the number of seeds owned by each player and in determining the winner of the game, after all seeds in both *lumbung* players (end game), illustrated in Figure 3.

Figure 3. The position of *Congklak* seeds after the end game

After each turn, a player must count the number of seeds in both *lumbung* players to determine their next strategy. This sum helps the player decide the right move to take the seeds from a particular hole.

Summation to determine the winner is when *Congklak* usually ends when one player has no beans in his/her *lumbung*. At that point, the player with seeds in his/her *lumbung* will collect the seeds. The winner is determined based on the number of seeds each player collects. In both cases, addition is crucial because it helps in the game, especially in determining the final result. Therefore, the traditional game of *Congklak* can be implemented into learning related to the concept of modulo and addition.

Here is one example of the implementation of the traditional game of *Congklak* on the concept of modulo (modulo operation) and addition:

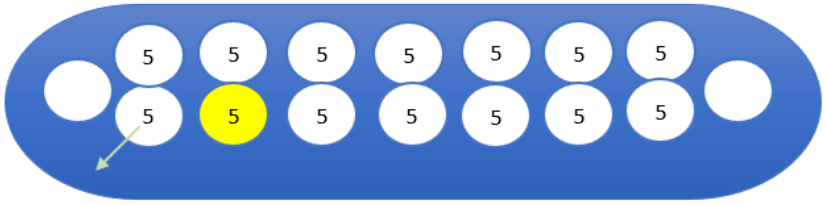

Figure 4. Result of modulo operation on the *Congklak*

In the game of *Congklak*, there is a traditional *Congklak* board with seven holes on each side (Figure 4). Player A is playing against player B. On player A's turn, he takes seeds from hole number 2 (the yellow hole) on his left side, taking 5 seeds. Determine the position of the last seed distributed and which hole will be filled with the seeds using the modulo operation!

From the information from this presented problem, we know that L_s is 2 (hole number 2), B is 5 (number of seeds taken), and n is 7 (number of holes). Furthermore, the question is which hole will be filled with the seeds using modulo operation. Using the formula, $L_e = (L_s + \mathrm{B} - 1)\ mod\ n$, we get $L_e = (2\ + 5 - 1)\ mod\ 7 = 6\ mod\ 7 = 6$ (the 6th hole). So, the last seed will be in the sixth hole, and the seeds taken from hole number 2 will be spread to the next hole (hole number 3) until hole number 6 because the last seed put into hole number 7 will be spread again if hole number 7 has another seed. So, the holes that are filled are holes number 3, 4, 5, and 6.

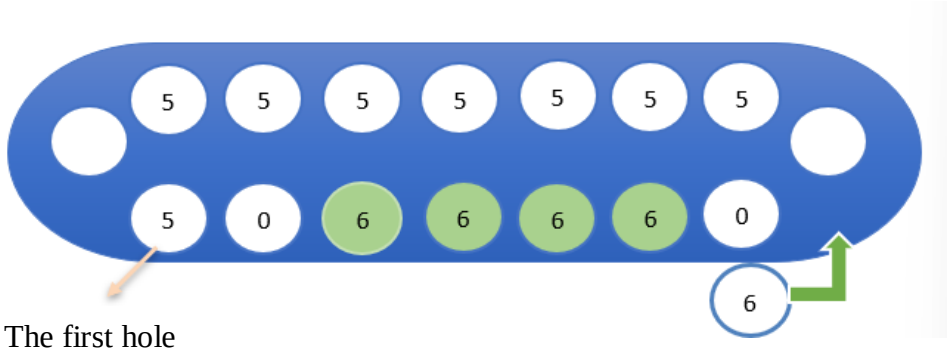

Figure 5. The result of modulo operation on *Congklak*

In the case illustrated in Figure 5, when player A picks up 5 seeds from hole number 2 on his left side, the seeds will be distributed to the following holes:

1. Hole number 3 (the first hole to be filled)
2. Hole number 4
3. Hole number 5
4. Hole number 6
5. Hole number 7 (the last hole passed before returning to the player's side)

Thus, player A, the last hole filled, or hole number 7, will get an extra turn to continue the game.

Research on the exploration of ethnomathematics in the traditional game of *Congklak* has revealed a relationship between cultural elements and mathematical concepts, specifically in the context of modulo operations. This finding aligns with several works, such as Alvisari et al. (2023), Yantoro et al. (2021), and Tusolihah et al. (2022), who explored ethnomathematics in *Congklak*-based learning. Their research established that cultural and mathematical elements are intertwined, demonstrating how this traditional game can be used to teach counting, addition, and subtraction to children from grades 1 to 3. While earlier studies focused on basic arithmetic, the recent exploration highlights the incorporation of modulo concepts, representing a broader mathematical framework.

The traditional game of *Congklak* is well-known in Indonesia, yet it is not indigenous to the country. Indonesia's rich history as a hub for spices and other natural resources has attracted various nations throughout history. This influx of people due to trade or war has contributed to cultural exchanges, making it challenging to pinpoint the exact origin of *Congklak*. Typically, the game is played with a wooden board, known as a *Congklak* board, and shells as game pieces. If shells are unavailable, players may use plant seeds or small stones, reflecting Indonesia's abundant natural and marine resources. This description of *Congklak* aligns with the one found on the Indonesian Intangible Cultural Heritage website, released on January 1, 2012. However, there's variation in board shapes across different regions. These differences in board design do not affect gameplay, though the names for the game may vary depending on the area.

Congklak is a game designed for two players, each with a set of tiny holes that constitute their playing area and a giant hole for storing seeds collected during the game. The seeds are distributed evenly among the smaller holes on the board, typically an odd number on each side. Players decide who goes first through a simple suit-up method. The seven small holes before each player represent the harvest cycle, with deeper philosophical ties to agricultural systems. They symbolize the days leading up to the harvest, while the large hole (*lumbung*) is where the harvest is stored.

The game's play emphasizes the values of patience, politeness, and ethics. It also cultivates skills like dexterity, sportsmanship, cooperation, and honesty, which are applicable beyond the game in everyday life. While playing, players learn to respect turns and conduct themselves with decorum. Moreover, *Congklak* subtly incorporates mathematical concepts, particularly modulo arithmetic. This concept is applied when players calculate the steps seeds must take from a specific hole. Modulo is essential to determine which holes will be filled as seeds are distributed in a specific order. If a player picks seeds from a particular hole, they are spread into successive holes, including one typically skipped, in a manner akin to modulo arithmetic. The use of modulo helps calculate the remainder after dividing a number by another number, effectively determining the seed distribution pattern on the *Congklak* board.

Strategy is crucial in *Congklak*, as players must calculate the position of the seeds to achieve the best outcome. In addition to the modulo concept, the game involves addition calculations to determine each player's total seed count at the end of the game. This aligns with the study of Supriadi et al. (2023), which found that *Congklak* contained mathematical elements. Unlike prior studies, which identified grade VII and IX materials, this research focused on the modulo concept and addition calculations.

Congklak is a medium for engagingly teaching math and training students in honesty, dexterity, sportsmanship, and cooperation (Kamid et al., 2021). Incorporating the game into education can make learning more enjoyable, reducing boredom through culturally rich activities (Risdiyanti et al., 2019; Hidayati & Prahmana, 2022). By presenting problems related to *Congklak*, like which holes seeds fill using modulo operations, students can learn mathematics while appreciating Indonesian cultural heritage, contributing to its preservation. Finally, this research explored *Congklak*, suggesting that traditional games can be a valuable learning resource for mathematics. Along with ethnomathematical insights, the cultural elements of history, philosophy, and gameplay provide additional context for educational purposes.

Conclusion

The research on the traditional game of *Congklak* reveals that the game's design reflects a strong connection with agricultural symbolism and offers rich ethnomathematical insights. *Congklak*'s seven-hole layout symbolizes the saving period before a harvest, with larger holes representing storage barns. Ethnomathematics explores the concept of modulo operations through the game's seed distribution, determining the last seed's position after each turn. Additionally, *Congklak* encompasses other mathematical elements, such as using addition to calculate the final scores to determine the winner.

However, this research has limitations, particularly regarding the generalizability of the findings. The study's focus was primarily on the concept of modulo operations and addition calculations, leaving other mathematical concepts potentially present in *Congklak* unexplored. Furthermore, the cultural context was limited to the agricultural symbolism, without delving into other philosophical or societal themes that might be relevant to different regions or communities. These limitations suggest that a broader exploration might yield a more comprehensive understanding of the game's cultural and mathematical significance.

For further research, it is recommended to expand the scope to explore additional mathematical elements in *Congklak* beyond modulo and addition, such as number patterns or spatial relations. Moreover, a more extensive cultural analysis could examine how *Congklak*'s symbolism and gameplay vary across different Indonesian regions, providing a deeper insight into the cultural diversity within the game. Researchers could also explore the educational applications of *Congklak* in teaching mathematical concepts, investigating its effectiveness as a learning tool in classroom settings to promote engagement and cultural awareness among students.

Acknowledgment

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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 entirely by the authors.

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