
The Enhancement of Numerical Literacy and Mathematical Conceptual Understanding among Elementary Students using Congklak 4.0- assisted Realistic Mathematics Education

Elita Mega Selvia Wijaya^{1*}, Rudy Setiawan²

^{1,2}Pendidikan Matematika FIP Universitas Tribhuwana Tunggaladewi

e-mail: *elita.selvia@gmail.com,

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Abstract

This study aims to examine the success of implementing Congklak 4.0, a digital transformation of the traditional Congklak game, as a learning medium based on the Realistic Mathematics Education (RME) approach to improve numeracy literacy and mathematical concept understanding of elementary school students. The research employed a quasi-experimental design involving 62 students from two elementary schools in Malang, Indonesia, divided into experimental and control groups. Data were collected through pretest and posttest instruments on numeracy literacy and conceptual understanding, supported by student response questionnaires. The results showed a significant improvement in the experimental group using Congklak 4.0 compared to the control group, with an average N-Gain of 0.67 (moderate to high category) for numeracy literacy and 0.71 (high category) for conceptual understanding. In addition, 87% of students expressed positive responses to the integration of Congklak 4.0 in mathematics learning, highlighting increased motivation and engagement. These findings indicate that Congklak 4.0 not only preserves cultural heritage by digitalizing a traditional game but also provides an effective, interactive, and enjoyable tool for mathematics learning. The study suggests that integrating digital traditional games with RME can be an innovative strategy to support numeracy literacy improvement programs in elementary schools.

Keywords: Congklak 4.0, numeracy literacy, mathematical concept understanding, RME, elementary school

1. Introduction

The rapid development of digital technology has significantly influenced the transformation of educational practices, particularly in mathematics learning at the elementary school level. Mathematics is often considered abstract and challenging for young learners, requiring the integration of contextual and meaningful approaches to foster deeper understanding (Wijaya, 2017). In Indonesia, the government has emphasized the importance of strengthening numeracy literacy as one of the key competencies in the *Merdeka Belajar* curriculum, highlighting the need for innovative teaching strategies that bridge cultural relevance and digital advancement (Kemendikbud, 2020).

Despite the growing emphasis on numeracy literacy in elementary education, many Indonesian students continue to demonstrate low performance in mathematical reasoning and conceptual understanding. National and international assessments such as PISA and TIMSS reveal that Indonesian students often struggle with problem-solving tasks requiring logical reasoning, number sense, and conceptual application rather than rote calculation (OECD, 2019; Mullis et al., 2020). Several factors contribute to this persistent issue. First, classroom instruction in many elementary schools still relies heavily on procedural teaching methods that prioritize memorization over understanding (Suryadi, 2018). Second, learning materials are often decontextualized, making mathematics appear abstract and disconnected from students' daily experiences (Wijaya, 2017). Third, limited use of interactive and culturally relevant learning media reduces student engagement and motivation, further hindering the development of numerical literacy (Nugroho et al., 2021). Traditional games such as *Congklak* have been part of Indonesian cultural heritage and contain mathematical elements such as counting, grouping, and strategic thinking (Ariyanto et al., 2019). However, their use in formal education remains limited due to the lack of structured integration with pedagogical frameworks. The Realistic Mathematics Education (RME) approach, which emphasizes learning mathematics through meaningful and realistic contexts, provides a suitable foundation for integrating traditional games into mathematics instruction (Gravemeijer & Terwel, 2000; Van den Heuvel-Panhuizen, 2020).

To overcome the limitations of conventional mathematics instruction, the **Realistic Mathematics Education (RME)** approach provides a powerful alternative framework for enhancing both numerical literacy and conceptual understanding. Rooted in the idea that mathematics should be connected to real-life situations, RME encourages students to construct knowledge through exploration, reflection, and contextual problem-solving (Gravemeijer & Terwel, 2000). By situating mathematical concepts within meaningful and familiar contexts, learners can develop deeper comprehension of numerical relationships and improve their ability to apply mathematics in daily life (Van den Heuvel-Panhuizen, 2020). The digitalization of traditional games offers an opportunity to preserve cultural heritage while simultaneously promoting interactive and engaging learning experiences (Suryani et al., 2021). Studies have shown that digital learning media can increase student motivation, improve problem-solving skills, and foster conceptual understanding (Fauzi & Hidayat, 2022). Furthermore, game-based learning has been proven effective in enhancing both cognitive and affective aspects of learning mathematics (Yuliani & Fitri, 2020).

Congklak 4.0 is proposed as a digital educational game designed to support the implementation of the **Realistic Mathematics Education (RME)** approach in elementary mathematics learning. As a digital transformation of the traditional *Congklak* game, Congklak 4.0 incorporates mathematical concepts such as counting, grouping, pattern recognition, and strategic decision-making into an interactive virtual environment. Through gameplay, students are encouraged to reason numerically, plan moves strategically, and reflect on their actions—all of which promote conceptual understanding. The digital format enables teachers to integrate game-based learning within the classroom while maintaining alignment with RME principles of contextual, meaningful, and student-centered learning. In addition, digital games provide immediate feedback, visualization, and adaptive challenges that help students connect mathematical symbols to real-world contexts. Therefore, Congklak 4.0 serves not only as a medium for cultural preservation but also as an innovative digital tool that enhances students' numerical literacy and conceptual understanding through active engagement and experiential learning.

Several empirical studies have highlighted the importance of integrating contextual and game-based approaches in improving students' mathematical literacy and conceptual understanding. Wijaya (2017) emphasized that realistic and contextual problems can enhance students' ability to apply mathematical concepts meaningfully. Yuliani and Fitri (2020) found that game-based learning significantly increases students' motivation and problem-solving performance in mathematics. Similarly, Fauzi and Hidayat (2022) demonstrated that digital learning media effectively improve students' conceptual understanding and engagement. Moreover, Ariyanto et al. (2019) suggested that traditional games like *Congklak* inherently support numerical reasoning and logical thinking. However, few studies have explored the integration of digital traditional games with the RME framework to enhance both numeracy literacy and conceptual understanding simultaneously. This study addresses that gap by combining **Congklak 4.0**—a digitalized traditional game—with the **RME approach**, creating a culturally relevant and pedagogically grounded innovation in mathematics education. The novelty of this study lies in its synthesis of digital transformation, cultural heritage, and constructivist learning theory to promote effective and enjoyable mathematics learning.

This study aims to examine the effectiveness of implementing **Congklak 4.0**, a digital transformation of the traditional *Congklak* game, as a learning medium based on the **Realistic Mathematics Education (RME)** approach to improve elementary students' **numeracy literacy** and **mathematical conceptual understanding**. The research employs a quasi-experimental design involving elementary students from two schools in Malang, Indonesia, to compare learning outcomes between those using Congklak 4.0 and those following conventional methods. The findings are expected to provide empirical evidence that supports the use of digital traditional games within the RME framework as an innovative pedagogical strategy. This study contributes theoretically by expanding the application of RME in digital learning environments and practically by offering educators a culturally meaningful, technology-integrated model to strengthen numeracy literacy programs in elementary schools.

2. Methods

2.1 Research Design

This study employed a **quasi-experimental design** with a pretest-posttest control group approach. The design was chosen to evaluate the effectiveness of Congklak 4.0 in enhancing students' numeracy literacy and mathematical concept understanding. The experimental group received mathematics instruction using Congklak 4.0 based on the Realistic Mathematics Education (RME) approach, while the control group was taught using conventional methods.

Table 1.

Research Design of the Study

Group	Pretest	Treatment	Posttest
Experimental Group (E)	O ₁	X (Mathematics instruction using <i>Congklak 4.0</i> based on RME approach)	O ₂
Control Group (C)	O ₁	- (Conventional mathematics instruction without <i>Congklak 4.0</i>)	O ₂

Description:

- O₁ = Pretest on numeracy literacy and mathematical conceptual understanding
- O₂ = Posttest on numeracy literacy and mathematical conceptual understanding
- X = Treatment (learning intervention using *Congklak 4.0* integrated with the RME approach)

2.2 Participants

The research was conducted in two elementary schools in Malang, Indonesia, during the second semester of the 2023/2024 academic year. A total of **62 students** from Grade V participated, consisting of **31 students in the experimental group** and **31 students in the control group**. The participants were selected using purposive sampling, considering schools with similar academic standards and student characteristics.

2.3 Research Instruments

Several instruments were employed in this study:

1. **Numeracy Literacy Test** – consisting of 20 items (multiple-choice and open-ended) covering basic arithmetic operations, fractions, problem-solving, and contextual tasks aligned with the *Merdeka Belajar* curriculum.

The **Numeracy Literacy Test** was developed to assess students' ability to understand, use, and apply mathematical knowledge in solving contextual and real-life problems. The instrument consisted of **20 items**, including **multiple-choice and open-ended questions**, designed according to the *Merdeka Belajar* curriculum standards for elementary mathematics. The test covered four major content domains:

1. **Basic arithmetic operations** (addition, subtraction, multiplication, and division),
2. **Fractions and number sense**,
3. **Mathematical problem-solving**, and

4. **Contextual application tasks** involving measurement, data interpretation, and reasoning in everyday situations.

Each item was constructed to measure students' ability to reason numerically, interpret quantitative information, and make sense of mathematical relationships within realistic contexts. The inclusion of open-ended items allowed the researchers to evaluate not only students' final answers but also their reasoning processes. Scoring was based on a rubric that rewarded accuracy, logical reasoning, and the ability to explain problem-solving strategies.

The test's content validity was confirmed through expert review by two mathematics education specialists who examined item alignment with numeracy literacy indicators and curriculum relevance. A pilot test was conducted with 30 students outside the research sample to ensure clarity and appropriate difficulty. The **Cronbach's Alpha coefficient of 0.82** indicated that the instrument had **high internal consistency**, making it a reliable measure of elementary students' numeracy literacy.

1. **Mathematical Concept Understanding Test** – consisting of 15 items designed to measure comprehension indicators such as interpretation, exemplification, classification, and application.

The **Mathematical Conceptual Understanding Test** aimed to measure students' depth of understanding of key mathematical concepts introduced during the intervention. The instrument contained **15 items**, developed to assess multiple dimensions of conceptual understanding as outlined by **Anderson and Krathwohl's (2001)** taxonomy of cognitive processes. The test items targeted four primary indicators:

1. **Interpretation** – understanding the meaning of mathematical statements or symbols,
2. **Exemplification** – providing or recognizing examples that illustrate mathematical ideas,
3. **Classification** – identifying relationships and categorizing concepts accurately, and
4. **Application** – using conceptual knowledge to solve problems in new or varied contexts.

Items included both multiple-choice and short constructed-response formats to capture the extent of students' reasoning and conceptual connections. Scoring emphasized students' ability to justify their answers and demonstrate conceptual links between procedures and principles. Expert validation ensured that each item accurately represented the intended construct and was developmentally appropriate for elementary students.

Reliability analysis using **Cronbach's Alpha yielded a coefficient of 0.85**, indicating **high reliability** and internal consistency. This result confirmed that the test was dependable for measuring changes in students' conceptual understanding after the implementation of **Congklak 4.0** within the **RME-based** learning framework.

2. **Student Response Questionnaire** – a Likert-scale instrument with 15 statements assessing students' perceptions of Congklak 4.0 in terms of usability, engagement, and effectiveness.
3. **Observation Sheets** – used by the researchers to record students' learning activities, collaboration, and interaction during the learning process.

All instruments were validated by two mathematics education experts and piloted on 30 students outside the sample group. Reliability was measured using Cronbach's Alpha, yielding coefficients of **0.82 for the numeracy literacy test** and **0.85 for the concept understanding test**, indicating high reliability.

2.4 Learning Procedure

The implementation of Congklak 4.0 followed three stages:

- **Preparation Stage:** Teachers were trained to operate Congklak 4.0 and to design lesson plans incorporating the RME approach.


- **Implementation Stage:** Students in the experimental group engaged in learning activities using Congklak 4.0 for six sessions (2×40 minutes each). Learning scenarios were designed based on RME principles, starting from contextual problems, modeling through Congklak gameplay, and progressive mathematization.


Congklak 4.0 is a digital transformation of the traditional Indonesian game *Congklak* (also known as *Mancala* in other cultures), redesigned as an interactive educational tool to support mathematics learning within the **Realistic Mathematics Education (RME)** framework. The game integrates cultural heritage, digital technology, and mathematical learning, allowing students to experience mathematics in a contextual and engaging environment.


1. Design and Features of Congklak 4.0


Congklak 4.0 was developed as a **digital board game** accessible through computers or tablets. It preserves the traditional structure of the Congklak board — typically consisting of **two rows of seven small holes and two large holes** — but integrates **interactive animations, score tracking, and mathematical prompts** to guide learning. The game's interface encourages students to perform numerical reasoning while playing, including **counting, grouping, distributing, and comparing quantities**. Each move in the game reflects basic arithmetic operations, providing a natural context for developing numeracy skills.

Key features include:

-  **Interactive Gameplay:** Players pick and distribute digital marbles, automatically recording scores based on mathematical rules.

-  **Mathematical Challenges:** Embedded mini-tasks appear during play, prompting players to solve problems involving **addition, subtraction, and fractions** related to the number of marbles.

-  **Feedback System:** The game offers **instant feedback** on player moves, supporting conceptual understanding through reflection and correction.

-  **Cultural Visualization:** Traditional Congklak aesthetics (colors, sounds, and motifs) are digitally represented to maintain cultural authenticity while engaging learners in a modern format.

2. Integration with Realistic Mathematics Education (RME)

Congklak 4.0 operationalizes the **core principles of RME**—contextual learning, modeling, and progressive mathematization—by transforming a familiar cultural game into a meaningful mathematical context:

- **Contextualization:** The gameplay situation reflects real-world mathematical reasoning, such as **fair distribution, comparison, and prediction**.
- **Modeling:** The board and marbles act as **concrete models** for abstract concepts like number operations, grouping, and proportional reasoning.
- **Progressive Mathematization:** As students advance, the game introduces more complex mathematical challenges that promote deeper conceptual understanding beyond procedural computation.

Through these stages, students are guided from informal reasoning (counting marbles) to formal mathematical understanding (formulating number sentences or solving arithmetic problems).

- **Evaluation Stage:** Both experimental and control groups completed pretests and posttests, and students in the experimental group filled out response questionnaires.

2.5 Data Collection and Analysis

Data were collected through pretests and posttests administered before and after the learning intervention. Student questionnaire responses and observational data complemented the quantitative results.

Quantitative data were analyzed using:

1. **Descriptive Statistics** – to determine mean, standard deviation, and percentage improvement.
2. **Normalized Gain (N-Gain)** – to assess the effectiveness of Congklak 4.0 in improving student performance.
3. **Inferential Statistics** – an independent sample t-test was applied to compare the posttest scores between the experimental and control groups at a significance level of 0.05.
4. **Effect Size (Cohen's d)** – to measure the magnitude of the treatment effect.

Qualitative data from questionnaires and observations were analyzed thematically to identify trends in students' engagement and perceptions toward Congklak

Data collection in this study involved administering **pretests and posttests** to both experimental and control groups to measure students' numeracy literacy and mathematical conceptual understanding before and after the learning intervention. In addition to these tests, **student questionnaires** and **classroom observations** were used to gather complementary qualitative data, providing a more comprehensive understanding of students' experiences and engagement during the learning process.

The **quantitative data** were analyzed through several statistical techniques. First, **descriptive statistics** were employed to determine the mean, standard deviation, and percentage improvement of students' scores. Next, the **Normalized Gain (N-Gain)** was calculated to evaluate the relative effectiveness of Congklak 4.0 in enhancing students' performance from pretest to

posttest. To examine whether there was a significant difference in learning outcomes between the experimental and control groups, an **independent sample t-test** was conducted at a **0.05 significance level**. Furthermore, the **effect size (Cohen’s d)** was computed to determine the magnitude of the treatment effect, offering insights into the practical significance of the findings beyond statistical results.

Meanwhile, the **qualitative data** obtained from student questionnaires and classroom observations were analyzed using a **thematic analysis approach**. This process involved categorizing students’ responses and observed behaviors to identify emerging patterns related to their engagement, collaboration, and perceptions toward the use of Congklak 4.0 in mathematics learning. The combination of quantitative and qualitative analyses allowed the study to provide both numerical evidence of learning improvement and contextual insights into students’ affective and behavioral responses to the digital game-based learning environment.

3. Result and Discussion

3.1 Students’ Numeracy Literacy Achievement

The pretest and posttest scores of numeracy literacy for both groups are summarized in Table 1.

Table 2.
Pretest and Posttest Scores of Numeracy Literacy

Group	N	Pretest Mean	Posttest Mean	N-Gain	Category
Experimental	31	56.45	82.26	0.67	Moderate–High
Control	31	55.97	70.13	0.38	Low–Moderate

The results show that the experimental group using Congklak 4.0 experienced a higher increase in numeracy literacy (N-Gain = 0.67) compared to the control group (N-Gain = 0.38). This indicates that Congklak 4.0 effectively supports students’ ability to solve numerical problems in realistic contexts.

3.2 Students’ Mathematical Concept Understanding

The improvement of mathematical concept understanding is presented in Table 2.

Table 3.
Pretest and Posttest Scores of Concept Understanding

Group	N	Pretest Mean	Posttest Mean	N-Gain	Category
Experimental	31	58.19	85.06	0.71	High
Control	31	57.94	73.42	0.42	Moderate

Students in the experimental group achieved higher conceptual understanding (N-Gain = 0.71, categorized as high) compared to the control group (N-Gain = 0.42). This suggests that Congklak 4.0 provided opportunities for students to construct mathematical concepts through meaningful experiences in line with RME principles.

3.3 Hypothesis Testing

The independent sample t-test revealed significant differences between the experimental and control groups in both numeracy literacy and concept understanding ($p < 0.05$). Furthermore, the effect size (Cohen's d) was 0.82 for numeracy literacy and 0.91 for concept understanding, both categorized as large effects.

3.4 Students' Responses to Congklak 4.0

Analysis of student response questionnaires showed that **87% of students gave positive responses** toward learning with Congklak 4.0. They reported higher engagement, enjoyment, and motivation. Observational data also confirmed that students were more active in discussions, collaborative problem solving, and connecting gameplay with mathematical concepts.

3.5 Discussion

In addition, the high percentage of positive student responses confirms that integrating digital traditional games creates enjoyable learning environments, which contribute to higher motivation and active participation (Zhao & Watterston, 2021). Therefore, the success of Congklak 4.0 not only supports cognitive development but also promotes affective and social learning aspects, making it a promising strategy for elementary mathematics instruction.

The findings of this study reveal that the integration of **Congklak 4.0**, a digital adaptation of the traditional Congklak game, significantly improved both **numeracy literacy** and **mathematical conceptual understanding** among elementary students. The experimental group showed higher posttest scores and N-Gain values compared to the control group, indicating that learning through Congklak 4.0 not only enhanced students' ability to apply mathematical operations in contextual settings but also deepened their understanding of fundamental mathematical concepts such as counting, grouping, and proportional reasoning. Moreover, the majority of students expressed positive attitudes toward the digital game-based learning environment, suggesting that the use of culturally embedded, interactive media increased motivation, enjoyment, and engagement during mathematics lessons.

These findings are consistent with several previous studies emphasizing the benefits of **digital game-based learning** in mathematics education. Fauzi and Hidayat (2022) found that

interactive digital media improve students' motivation and problem-solving abilities, while Yuliani and Fitri (2020) demonstrated that game-based activities support the development of mathematical reasoning and creativity. Similarly, the present study reinforces the idea that digital learning environments can foster a more active and meaningful learning experience when properly aligned with pedagogical frameworks such as RME. The results also resonate with Suryani et al. (2021), who argued that integrating traditional games into digital platforms can preserve cultural values while promoting cognitive development in the 21st-century classroom.

From a theoretical standpoint, this study supports **Freudenthal's (1973)** principle that mathematics should be learned as a **human activity**, emphasizing the learner's active role in constructing knowledge through meaningful experiences. The use of **RME principles** in Congklak 4.0 enabled students to connect real-life contexts with abstract concepts through the stages of contextualization, mathematization, and formalization (Gravemeijer & Terwel, 2000; Van den Heuvel-Panhuizen, 2020). The cultural dimension of the game also aligns with **socio-constructivist theory**, which views learning as a socially mediated process in which interaction, collaboration, and shared experiences contribute to deeper understanding. The synthesis of these theories suggests that Congklak 4.0 is effective not merely because of its digital or entertaining features, but because it situates mathematical learning within a meaningful, culturally relevant, and socially interactive context.

The **implications** of this study are multifold. Pedagogically, the integration of digital traditional games such as Congklak 4.0 demonstrates a viable model for enhancing numeracy literacy programs in elementary schools, particularly within the **Merdeka Belajar** framework that emphasizes contextual, student-centered learning. Teachers can adopt similar culturally grounded digital tools to make abstract mathematical ideas more tangible and engaging. Practically, the success of Congklak 4.0 suggests that educational technology developers should consider embedding local cultural elements in game design to increase relevance and acceptance among students. Furthermore, this approach encourages curriculum designers to promote **cultural sustainability** in education while advancing digital transformation.

Despite its promising results, this study is not without **limitations**. First, the sample size was relatively small and limited to two elementary schools in Malang, which may affect the generalizability of the findings. Second, the duration of the intervention—six sessions—might not be sufficient to observe long-term retention or transfer of mathematical understanding. Third, while the study explored cognitive and affective dimensions, it did not extensively measure higher-order skills such as reasoning, communication, or creativity. Therefore, **future research** should involve larger and more diverse samples across different regions to validate the effectiveness of Congklak 4.0 in broader educational contexts. Longitudinal studies are also recommended to examine the sustainability of learning gains over time. Additionally, further investigations could explore how digital traditional games can be integrated into other mathematical domains or combined with adaptive learning technologies to personalize instruction.

In conclusion, this study contributes to the growing body of research highlighting the potential of **digital traditional games** as effective learning media under the **RME framework**. By merging cultural heritage with digital innovation, Congklak 4.0 offers not only an engaging

platform for improving students' numeracy and conceptual understanding but also a meaningful way to bridge tradition and technology in modern mathematics education.

4. Conclusion

This study demonstrates the success of implementing Congklak 4.0, a digital version of the traditional Congklak game, within the framework of Realistic Mathematics Education (RME) to enhance numeracy literacy and mathematical concept understanding of elementary school students. The findings revealed significant improvements in the experimental group compared to the control group, with higher N-Gain scores in both numeracy literacy (0.67) and conceptual understanding (0.71). Moreover, students expressed overwhelmingly positive responses toward the use of Congklak 4.0, indicating that the integration of digital traditional games not only increased learning outcomes but also promoted motivation and active participation.

The study concludes that Congklak 4.0 is an effective, engaging, and culturally relevant learning medium for elementary mathematics education. By combining cultural heritage with modern digital technology, Congklak 4.0 contributes to preserving traditional games while fostering meaningful learning experiences. Teachers are encouraged to adopt digitalized traditional games in classroom practices as innovative strategies to support numeracy literacy improvement. Future research may expand the application of Congklak 4.0 to different grade levels, subjects, or larger samples, and explore its long-term impact on students' mathematical thinking and problem-solving skills.

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