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Research Article

The Effectiveness of RUBIC Interactive Games in Improving Early Childhood Numeracy and Grouping Skills

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Abstract

Early childhood cognitive development can be optimally enhanced through engaging and interactive learning media. This study examines the effectiveness of RUBIC (Ruang Belajar Interaktif Numeric**)**, an interactive educational game, in improving counting and categorizing skills among young children. This research employed a quantitative approach with a one-group pre-test and post-test experimental design. The participants comprised 15 children from Group B at TK Saraswati during the even semester of the 2024/2025 academic year. Data were collected through observation, documentation, and tests, using pre-test and post-test items and observation sheets as instruments. The data were analyzed using the Wilcoxon Signed-Rank Test and normalized gain (N-Gain) analysis. The results showed significant improvement after implementing the RUBIC game ($p = 0.001$). The average counting score increased from 64.7% to 97.8%, while the categorizing score rose from 66.1% to 99.2%. The N-Gain values for counting and categorizing were 0.4277 and 0.4093, respectively, falling into the moderate improvement category. These results demonstrate increased learning achievement levels from "adequate" to "very high." However, the study is limited by its small sample size and the absence of a control group. Future research is recommended to involve a larger sample and a more robust experimental design to validate and expand upon these findings.

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INTRODUCTION

Education is understood as a planned and systematic process to create a learning environment that supports the development of individual potential. Learning plays a vital role in shaping superior human resources, as emphasized in the fourth paragraph of the Preamble to the 1945 Constitution regarding the importance of educating the nation. In the national education system, the curriculum is a fundamental element that guides all learning activities (Munandar, in Suyono & Hariyanto, 2011). Based on Law No. 20 of 2003, the curriculum includes objectives, content, teaching materials, and methods as guidelines for learning activities. The evolution of the curriculum in Indonesia reflects its response to the dynamics of the times, from the 1947 curriculum to the current Merdeka Curriculum, which emphasizes contextual learning, learner-centered approaches, and differentiation (Indarta et al., 2022).

In early childhood education (PAUD), the Merdeka Curriculum applies the "Merdeka Bermain" (Free to Play) approach, which places children at the center of learning. Guidelines from the Ministry of Education, Culture, Research, and Technology (2024) emphasize that teachers should design learning based on local contexts and children's characteristics. This approach allows play activities to be the primary means for

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exploration and the comprehensive development of children's potential. Research by (Putri Manik & Khadijah, 2024) reinforces that the Merdeka Curriculum in kindergarten encourages children to freely express their ideas in an active and exploratory learning environment. Thematic learning is the primary strategy because it can integrate various aspects of children's development, including cognitive, social, emotional, and physical elements (Dian Fitra, 2023).

Cognitive development in early childhood, especially at the kindergarten level, is an essential foundation in shaping thinking patterns, analytical skills, and problem-solving. (Keating, 2020) Chapter 3, Cognitive and Brain Development of the Handbook of Child Psychology and Developmental Science, emphasizes that childhood is a sensitive period that requires appropriate cognitive stimulation to have a long-term impact on academic achievement. Numeracy is one of the essential forms of stimulation at this stage. In kindergarten, numeracy learning is conducted through concrete and enjoyable activities such as recognizing numbers, arranging patterns, and counting real objects, which help develop logic, concentration, and problem-solving skills. Engaging, contextual, and age-appropriate media ensure that numeracy activities are effective and meaningful. (Noviarini et al., 2025).

However, reality shows that not all kindergartens have implemented an optimal approach to numeracy learning. Based on initial observations at Saraswati V Kindergarten, teachers still use simple media such as mango leaves as learning aids for numeracy in the "Fruit Plants" theme. Although thematically relevant, this media does not adequately support the multisensory needs of young children, who tend to learn through visual stimuli, movement, and direct interaction. When the press fails to spark children's enthusiasm, their motivation and focus for learning quickly diminish.

Counting and classifying are integral to children's cognitive development and form the foundation for building number sense, which is crucial for future educational levels. (Prayitno et al., 2023) emphasize that developing number sense at an early age will help children understand numerical concepts and symbols in various real-world contexts. Therefore, alternative media that align with children's characteristics are needed. One potential solution is using educational games combining play and learning elements. (Oktary et al., 2024) explain that educational games can enhance active participation, conceptual understanding, and children's engagement in enjoyable numeracy learning. Educational games not only serve as entertainment but also as strategic pedagogical tools (Skene & Cooper, 2022; Wang et al., 2022; Miller, 2018). However, other studies highlight challenges associated with using digital media among young children, such as decreased attention span, sleep disturbances, and reduced direct social interaction (Neumann, 2020; American Academy of Pediatrics, 2016). This underscores the importance of designing media that is not only engaging but also aligned with children's developmental characteristics and learning contexts. Nevertheless, previous studies have not extensively investigated the effectiveness of interactive digital media tailored to local needs and designed explicitly for numeracy learning in early childhood education.

This study offers novelty through the use of RUBIC (Interactive Numeric Learning Space), a digital-based educational game developed to train counting and grouping skills in a fun way, in line with the characteristics of early childhood and consistent with the principles of the Merdeka Curriculum. This study aims to test the effectiveness of RUBIC in improving these two basic numeracy skills. The results are expected to provide practical contributions to the development of numeracy learning media in early childhood education and strengthen theoretical research on the integration of interactive digital media in early childhood education.

METHOD

This study uses a quantitative approach with a pre-experimental design, namely the One-Group Pretest-Posttest Design. This design was chosen because it allows researchers to observe the impact of treatment on the same group by comparing conditions before and after the intervention. This experimental method is highly relevant in education for testing a treatment's effectiveness under controlled conditions (Sugiyono, 2013).

The following is the design according to Sugiyono (2013)

Table 1. Research Design

Pretest	**Treatment**	***Posttest***
O_1	X	O_2

The research subjects were 15 children from group B2 at Saraswati V Kindergarten. The sample was selected using saturated sampling because the population was fewer than 30 children. This research consisted of three stages: pre-, experiment, and post-experiment. It was conducted in three sessions. Session one is pretest measurement of children's numeracy skills (counting and grouping) using an observation sheet instrument without the RUBIC game media. Session two is treatment, numeracy learning with the theme of Mango Plants using the RUBIC (Interactive Numeric Learning Space) educational game media. No assessment was conducted at this stage, but two observers monitored the learning process to ensure the intervention proceeded as planned. Session three is post-test Children's numeracy skills were reassessed using the same observation sheet instrument as in the pretest stage.

According to Arikunto (2010), data collection techniques are methods researchers can use to collect data. The choice of technique depends on the type of data to be collected. In this study, the researcher collected information by preparing three data collection techniques: observation, documentation, and testing. The instrument's validity was tested through product-moment correlation analysis using SPSS version 26, with items declared valid if $r \geq 0.514$. The test results showed that all items in the counting variable were valid, while in the grouping variable, one item was not valid. Reliability was tested using Inter-Rater Reliability with the Intraclass Correlation Coefficient (ICC) approach because the data were on a Likert scale. The counting variable had an ICC single measures of 0.891 and average measures of 0.942 ($p = 0.000$), while the grouping variable had an ICC single measures of 0.922 and average measures of 0.959 ($p = 0.000$). These values fall into the category of excellent reliability (Koo & Li, 2016).

Data were analyzed using descriptive statistics to calculate the mean, maximum, minimum values, and standard deviation. This descriptive approach was chosen considering the limited sample size and the characteristics of the subjects in the early stages of development, in line with Mertler's (2017) view that research on young children often requires descriptive analysis to obtain a general picture of the phenomenon.

Before analyzing the results, the researcher first established assessment criteria as a basis for classification. These criteria were compiled based on the conversion of percentages to the maximum score for each variable, then classified into five quality categories, namely**:**

Table 2. Assessment Criteria

Score	***Category***
86-100%	Excellent
71-85%	Good
56-70%	Fair
41-55%	Poor
≤40%	Very Poor

RESULT AND DISCUSSION

Result

This study is an experimental study that applies educational technology, specifically in the utilization category. This area emphasizes how media and technology are used effectively in learning (Saettler, 2004; Munir, 2012). In this study, the utilization category is realized through the use of educational games as a means to improve the ability to count and classify fruits in young children in a kindergarten environment. The research subjects were 15 children from group B2 at Saraswati Kindergarten, selected using purposive sampling. The

media used was the educational game RUBIC, designed to stimulate children's basic cognitive skills, particularly in numeracy and object classification.

To understand the patterns of achievement improvement more comprehensively, complete data on total scores and averages for each variable are presented in the diagram below. Bar charts were chosen because they can present data visually and systematically, making it easier for readers to clearly compare pre-test and post-test results. This aligns with the statement (Suprihatin, 2021) that bar charts are highly effective in presenting data because they can help improve the visual understanding of the data presented.

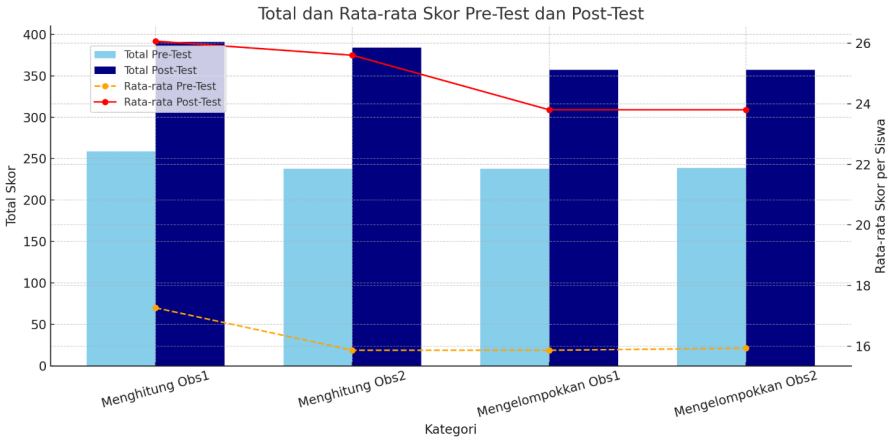


Figure 1. Overall Bar Chart

Based on the results obtained from observing the calculation variable, there was a significant increase between the pre-test and post-test results. The first observer recorded a total score for all students, increasing from 259 to 391. Meanwhile, the second observer recorded an increase from 238 to 384. When looking at the average score per student, there was an increase from 17.27 to 26.07 for the first observer, and from 15.87 to 25.6 for the second observer. When converted into percentages, the average student achievement increased from approximately 64.7% to 97.8% for the first observer and from 59.5% to 96% for the second observer. Based on the assessment criteria, these results indicate a shift in category from satisfactory to very good.

In the grouping variable, there was also a consistent increase in scores. The first observer recorded a total score increase from 238 to 357, while the second recorded an increase from 239 to 357. The average score per student rose from 15.87 to 23.8 for both observers. When converted into percentages, the average student achievement increased from 66.1% to 99.2% for the first observer and from 66.4% to 99.2% for the second observer. The achievement percentage on the post-test for both observers showed the exact figure because the total score obtained after the treatment was also identical, namely 357. This similarity in results reinforces the consistency of assessment between observers. It indicates that the improvement in students' ability to classify occurred evenly and significantly after the learning intervention was provided.

To provide a clearer picture of the increase in scores for each variable based on the observations of the two observers, the achievement data in the form of percentages and the magnitude of the rise are presented in the following table:

Table 3. Overall Results

Variable	Observer	Pre-Test (%)	Post-Test (%)	Category Increase
Counting	Observer 1	64,7%	97,8%	Fair → Very Good
Counting	Observer 2	59,5%	96,0%	Fair → Very Good
Grouping	Observer 1	66,1%	99,2%	Fair → Very Good
Grouping	Observer 2	66,4%	99,2%	Fair → Very Good

To ensure the validity of the research findings, particularly in quantitatively interpreting changes in pretest and posttest scores, the researcher analyzed the data distribution using a normality test. A normality test is necessary to determine whether the data obtained is normally distributed, so that the type of inferential statistical test can be adjusted to the characteristics of the data. In this study, the normality test was performed using the Shapiro-Wilk method because the number of research subjects was 15 children, where the Shapiro-Wilk is more recommended for small samples (n < 50) (Razali & Wah, 2011).

Table 4. *Results of Normality Test of Pretest and Posttest Data Using Shapiro-Wilk*

Variable	Sig. (Shapiro-Wilk)
Pre-Test Counting	0.024
Post-Test Counting	0.553
Pre-Test Grouping	0.187
Post-Test Grouping	0.662

Based on the results in Table 4.1, it is known that the significance value for the Pre-Test Counting variable is 0.024, which is smaller than the significance limit of 0.05. This indicates that the data is not normally distributed. Meanwhile, the Post-Test Counting variable (p = 0.553), Pre-Test Grouping variable (p = 0.187), and Post-Test Grouping variable (p = 0.662) show significance values above 0.05, meaning that the data for these three variables are normally distributed.

Although most data meet the normality criteria, one non-normal variable indicates that the overall data distribution is not entirely homogeneous. Therefore, to maintain the validity and accuracy of the analysis results and avoid violating the assumptions of parametric tests, the researcher used the non-parametric Wilcoxon Signed-Rank Test as the advanced analysis method. The Wilcoxon test is considered more appropriate for data that is not normally distributed, ordinal, or small in size (Pallant, 2010; Gibbons & Chakraborti, 2011), making it suitable for the characteristics of the data in this study.

Table 5. *Results of the Wilcoxon Signed-Rank Test*

Variable	N	Z	Asymp. Sig. (2-tailed)	Interpretation
Counting	15	-3.296	0.001	Significant (p < 0.05)
Grouping	15	-3.180	0.001	Significant (p < 0.05)

Based on the results of the Wilcoxon Signed-Rank Test, the Asymp. Sig. (2-tailed) The value was 0.001 for counting ability and 0.001 for grouping ability. These significance values are smaller than the significance level of 0.05, so there is a significant difference between the pre-test and post-test results. Thus, the educational media used in this study have a positive effect on improving children's abilities.

Although the Wilcoxon test shows a significant difference, this test does not provide information on the extent of the improvement in learning outcomes. Therefore, the Normalized Gain (N-Gain) value was calculated to determine the effectiveness of the learning media used. The N-Gain calculation can indicate the improvement category, such as high, moderate, or low, making the research results more comprehensive. According to Hake (1998), the N-Gain calculation is an appropriate method for assessing the effectiveness of a learning intervention on learning outcomes.

Table 6. *N-Gain Score Results*

Variable	N	Min	Max	Mean	Std. Deviation

N-Gain Counting	15	0.17	0.77	0.4277	0.16180
N-Gain Grouping	15	0.23	0.58	0.4093	0.11015

Based on the results of the Wilcoxon Signed-Rank Test, the Asymp. Sig. (2-tailed) The value was 0.001 for counting ability and 0.001 for grouping ability. These significance values are smaller than the significance level of 0.05, so there is a significant difference between the pre-test and post-test results. Thus, the educational media used in this study have a positive effect on improving children's abilities.

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Discussion

The results of this study indicate that the use of RUBIC educational games significantly improves the counting and grouping abilities of young children, with a change in category from "fair" to "very good." Although the final results show a high level of mastery, the N-Gain values for both abilities are in the moderate category (0.4277 for counting and 0.4093 for grouping). This indicates consistent improvement, but there is still room for optimization. In other words, although the final results show high proficiency, the rate of change remains moderate, leaving room for further optimization in the future.

This finding is in line with the results of a study (Putri et al., 2024) at PGRI At-Taqwa Kindergarten, which showed that educational games effectively increase active engagement and stimulate children's cognitive development. Using a combination of audio and visual elements in RUBIC supports children's focus on learning, as evidenced by Satriana et al. (2023), who found that audiovisual media can enhance measurement skills and concentration in children aged 5–6 years. From the perspective of cognitive development theory, these results are also consistent with the view of Piaget (1964) that young children are in the preoperational stage, where concrete learning that captures their attention facilitates the development of simple logic.

However, critical analysis of the results shows that the moderate N-Gain achievement may be due to several factors. First, the short duration of the intervention (three meetings, each lasting 2 JP) limited the children's opportunities to practice and internalize the skills optimally. Second, part of the learning time was spent on initial adaptation to digital media, especially for children not accustomed to using interactive devices. This situation aligns with the novelty effect phenomenon, where initial interest in new media can temporarily boost motivation but may not necessarily lead to long-term improvements (Clark, 1983).

In addition, the role of teachers in this intervention also had a significant effect. Teachers acted as technical facilitators and provided scaffolding that helped children understand instructions, maintain focus, and stay motivated during the learning process. This supports Vygotsky's (1978) theory about the importance of social interaction and structured support in achieving the zone of proximal development. Teachers' positive reinforcement, such as verbal praise or gestural encouragement, likely also influences children's engagement and learning outcomes.

The implications of this research are both practical and theoretical. The RUBIC educational game medium can be integrated into early childhood education as a strategy for developing numeracy skills enjoyably and interactively. Long-term interventions, consistent repetition sessions, and teacher training in digital media management are recommended to maximize the impact. Theoretically, these findings enrich the evidence that the integration of game-based technology not only impacts cognitive learning outcomes but also has the potential to improve executive functions such as attention, working memory, and self-control. Further research

could examine the long-term impact of using this media, including knowledge retention and skill transfer to other learning contexts.

CONCLUSION

This study shows that using RUBIC educational games on children in class B2 at Saraswati V Kindergarten improved their counting and grouping skills. There was a shift in achievement from the "fair" category to "very good" after the intervention, indicating that the children achieved high learning outcomes. Statistical test results confirm the improvement was quantitatively significant, with an average N-Gain value in the moderate category. This indicates that the improvement process from the starting point to the outcome progressed positively, but was not yet optimal. However, this study has limitations, including a relatively small number of subjects (15 children) and the absence of a control group for comparison, so the findings should be generalized with caution. In addition, the short duration of the intervention may affect the level of skill internalization by children.

The practical implications of these findings are that kindergarten teachers and early childhood education curriculum developers may consider using interactive digital media such as RUBIC to enhance basic cognitive skills, ensuring the inclusion of repetition sessions, adequate adaptation to the media, and consistent teacher guidance to achieve more optimal results.

For future research, it is recommended to involve a larger number of subjects, use an experimental design with a control group, and expand the scope of variables measured. This approach is expected to provide a more comprehensive understanding of the effectiveness of digital learning media across various early childhood education contexts.

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