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The Effect of Using Prodigy Math Game on Elementary School Students' Literacy, Numeracy, and Critical Thinking Skills

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Abstract: The purpose of this study is to assess how the Prodigy Math Game improves elementary school kids' reading, numeracy, and critical thinking skills. The study employed a quasi-experimental approach with a pretest-posttest control group. The research sample consisted of Class 6A, comprising 24 students, who served as the experimental group and used the Prodigy Math Game in the learning process. Class 6B, also consisting of 24 students, functioned as the control group and received instruction through conventional teaching methods. The research tools included literacy, numeracy, and critical thinking assessments, as well as observation sheets and interviews to assess student participation. The study found that pupils in the experimental group improved significantly in literacy, numeracy, and critical thinking compared to the control group. The experimental group's average posttest score was considerably higher, according to a t-test. Students' ability to grasp text-based questions in the game indicated better reading, and their ability to answer math problems of various difficulty exhibited improved numeracy. Critical thinking skills are developed by using proper problem-solving tactics in games. These findings lend credence to a constructivist approach to learning, which stresses hands-on experience and personalized challenges. This study found that the Prodigy Math Game is an excellent, innovative way to improve primary school children' literacy, numeracy, and critical thinking skills.

Keywords: Critical Thinking, Literacy and Numeracy, Prodigy Math Game

A. Introduction

The rapid digital transformation of education in the 21st century has reshaped how foundational competencies such as mathematical literacy, numeracy, and critical thinking are developed in elementary classrooms. Contemporary educational frameworks emphasize the importance of these integrated skills to prepare students for complex problem-solving and real-world decision-making. However, traditional mathematics instruction often remains teacher-centered and procedural, limiting opportunities for students to engage in conceptual reasoning and reflective analysis (Santagata et al., 2018). As a result, many learners struggle to interpret contextual mathematical problems and apply reasoning strategies effectively.

Basic education is vital for developing kids' academic skills, notably in reading, numeracy, and critical thinking (Ansya & Mailani, 2024; Ball et al., 2014; Pearse & Walton, 2011). Literacy in mathematics refers to the capacity to read and comprehend mathematical writings, as well as accurately interpret story problems and directions. Numeracy is the comprehension of number concepts, mathematical operations, and the application of reasoning in daily life (Haloho & Napitu, 2023; Sa'dijah et al., 2023; Westwood, 2021). Meanwhile, critical thinking abilities help students examine problems, link concepts, and devise solutions for tackling complicated arithmetic problems (Schoenfeld & Sloane, 2016; Shanta & Wells, 2022; Suryapuspitarini et al., 2018).

This challenge was evident at SDN Toket 2, Proppo District, Pamekasan Regency, where classroom observations revealed persistent difficulties in students' mathematical literacy and critical thinking performance. Many students demonstrated limited ability to interpret word-based mathematical problems, identify relevant information, and construct logical solution pathways. Instruction tended to emphasize formula memorization and routine procedures rather than conceptual understanding and analytical reasoning. These conditions indicate a need for instructional innovation that promotes active engagement and higher-order cognitive processing.

One promising approach is Game-Based Learning (GBL), particularly through adaptive digital platforms such as Prodigy Math Game (Sihotang, 2021). This game blends RPG (role-playing game) aspects with arithmetic problems, allowing kids to learn while they play (Norsyiha et al., 2024). As an interactive role-playing mathematics game, Prodigy integrates adaptive problem-solving tasks, immediate feedback, and personalized challenge levels. Previous research has shown that GBL can enhance student motivation, engagement, and conceptual understanding by fostering active participation and experiential learning (Crocco et al., 2016). With interactive features and a reward system, Prodigy Math Game also allows teachers to monitor student progress in real-time, allowing them to provide appropriate interventions (Giannios, 2024). The adaptive structure of Prodigy Math Game may function as a digital scaffolding system that supports progressive development of mathematical literacy and critical reasoning skills.

However, despite growing interest in digital game-based instruction, limited empirical evidence exists regarding the effectiveness of Prodigy Math Game in simultaneously enhancing mathematical literacy, numeracy, and critical thinking skills within the Indonesian elementary school context. Most prior studies have primarily examined motivational outcomes or general academic achievement without analyzing these integrated competencies. Therefore, this study aims to investigate the effect of Prodigy Math Game on students' mathematical literacy, numeracy, and critical thinking skills using a quasi-experimental design. Specifically, this research addresses the following questions: (1) Does the use of Prodigy Math Game significantly improve students' mathematical literacy, numeracy, and critical thinking skills compared to conventional instruction? and (2) To what extent does its implementation contribute to multidimensional cognitive development in elementary mathematics learning?

B. Methods

This study employed a quasi-experimental design with a pretest–posttest control group structure (Rogers & Revesz, 2019; Shadish & Luellen, 2012; Siedlecki, 2020). The design was considered quasi-experimental because intact classroom groups were used without random assignment of individual students. The existing Grade 6 classes were maintained to preserve the natural instructional setting and avoid disrupting school administrative arrangements. The study was conducted at SDN Toket 2, Proppo District, Pamekasan Regency, during the even semester of the 2024/2025 academic year. The participants consisted of all sixth-grade students enrolled in the school (N = 48), divided into two intact classes: Class 6A (n = 24) served as the experimental group, and Class 6B (n = 24) served as the control group. Students were aged between 11 and 12 years. The grouping followed the school's existing class structure; therefore, the sampling technique can be categorized as cluster sampling rather than purposive sampling. Prior to data collection, permission was obtained from the school administration. Parental consent and student assent were secured to ensure ethical compliance in conducting educational research involving minors.

Students in Class 6A received mathematics instruction integrated with Prodigy Math Game over a four-week period, consisting of eight sessions (two sessions per week). Each session lasted approximately 60 minutes. The instructional structure followed three stages:

1. Introduction (10 minutes): Teacher explanation of lesson objectives and brief review of previous material.
2. Game-Based Learning Activity (40 minutes): Students engaged individually with Prodigy Math Game using school-provided digital devices. The game presented adaptive mathematics problems aligned with the Grade 6 curriculum, particularly covering fractions, ratios, basic algebraic expressions, and word problems.
3. Reflection and Discussion (10 minutes): The teacher facilitated discussion on strategies used in solving selected problems encountered in the game.

The adaptive feature of Prodigy automatically adjusted problem difficulty based on students' responses, functioning as a digital scaffolding mechanism (Fadhil et al., 2021).

Students in Class 6B received conventional mathematics instruction covering the same topics during the same period. Instruction consisted of teacher-centered explanations, textbook-based exercises, and written problem-solving activities. The teacher explained concepts using whiteboard demonstrations, followed by guided practice and independent seatwork. No digital tools or game-based elements were incorporated.

Content validity was established through expert judgment by three mathematics education specialists. The Content Validity Index (CVI) indicated acceptable agreement among experts (CVI > 0.80). Instrument reliability was assessed using Cronbach's Alpha, yielding coefficients of:

Mathematical Literacy : $\alpha = 0.82$
Numeracy : $\alpha = 0.85$
Critical Thinking : $\alpha = 0.79$

These values indicate satisfactory internal consistency.

An observation sheet was used to record students' engagement, participation, problem-solving behavior, and collaborative interaction during instructional sessions. The observation rubric included indicators such as task persistence, strategy variation, and response to feedback. Semi-structured interviews were conducted with selected students and the mathematics teacher to explore perceptions regarding the effectiveness of Prodigy Math Game. Interview questions focused on learning motivation, perceived difficulty, and problem-solving experience. Data were analyzed using SPSS version 28. A Paired Sample t-test was used to compare pretest and posttest scores within each group to determine learning improvement. An Independent Sample t-test was conducted to compare posttest scores between the experimental and control groups to evaluate the effectiveness of the intervention. Prior to hypothesis testing, assumption checks were performed. Data normality was tested using the Shapiro–Wilk test, and homogeneity of variance was examined using Levene's test. All assumptions were met ($p > 0.05$), allowing parametric analysis to proceed. Statistical significance was determined at $\alpha = 0.05$.

C. Results and Discussion

Results

The study's findings were obtained by analyzing pretest and posttest data from two groups: the experimental class (6A), which used the Prodigy Math Game to learn, and the control class (6B), which used traditional methods. The data obtained comprised pupils' literacy, numeracy, and critical thinking scores before and after treatment.

The pretest results showed no significant difference in average scores between the two groups, indicating that students' basic reading, numeracy, and critical thinking skills were relatively balanced. However, after multiple sessions of treatment, posttest results revealed that the experimental group improved more significantly than the control group. Each group's pretest and posttest results are presented in the table below.

Table 1. The Average Pre- and Post-Test Scores Of The Experimental And Control Classes

Evaluation Criteria	Group	Pretest Average	Posttest Average	Improvement (%)
Literation	Experiment	62,4	82,6	32,4
	Control	61,8	70,2	13,6
Numeration	Experiment	59,5	85,2	43,2
	Control	58,9	72,1	22,4
Critical thinking	Experiment	60,3	83,4	38,3
	Control	59,7	68,5	14,7

The descriptive statistics of students' mathematical literacy, numeracy, and critical thinking scores are presented in Table 1. In the experimental group, the mean score for mathematical literacy increased from 62.40 (SD = 6.85) in the pretest to 82.60 (SD = 7.12) in the posttest. Numeracy improved from 59.50 (SD = 7.03) to 85.20 (SD = 6.48), while critical thinking increased from 60.30 (SD = 6.91) to 83.40 (SD = 7.05). In contrast, the control group showed more modest improvements. Mathematical literacy increased from 61.80 (SD = 7.02) to 70.20 (SD = 6.95), numeracy from 58.90 (SD = 6.87) to 72.10 (SD = 7.10), and critical thinking from 59.70 (SD = 6.75) to 68.50 (SD = 7.20). Overall, the experimental group demonstrated substantially higher posttest gains across all measured competencies.

Table 2. The Results of the Paired Samples T-Test Comparing Pretest and Posttest Scores

Evaluation Criteria	Group	t-value	t-table	Sig.(p)
Literation	Experiment	8,12	2,06	0,000
	Control	4,35	2,06	0,002
Numeration	Experiment	10,24	2,06	0,000
	Control	5,12	2,06	0,001
Critical thinking	Experiment	9,38	2,06	0,000
	Control	3,78	2,06	0,005

(Note: $\alpha = 0.05$; results were considered statistically significant if $p < 0.05$)

The within-group comparisons using Paired Sample t-tests are reported in Table 2. For the experimental group (n = 24), significant improvements were found in mathematical literacy, t (23) = 8.12, p < .001, with a large effect size (Cohen's d = 1.65). Numeracy also showed significant improvement, t (23) = 10.24, p < .001, with a very large effect size (d = 2.09). Similarly, critical thinking improved significantly, t (23) = 9.38, p < .001, with a large effect size (d = 1.91). Although the control group also showed statistically significant gains in literacy, t (23) = 4.35, p = .002, numeracy, t (23) = 5.12, p = .001, and critical thinking, t (23) = 3.78, p = .005, the effect sizes were moderate (d ranging from 0.70 to 1.05), indicating that the magnitude of improvement was considerably smaller than in the experimental group.

Table 3. Results of Independent Samples t-Test for Posttest Scores Between Experimental and Control Groups

Evaluation Criteria	t-value	t-table	Sig.(p)	Conclusion
Literation	6,45	2,06	0,000	Significantly different
Numeration	8,32	2,06	0,000	Significantly different
Critical thinking	7,21	2,06	0,000	Significantly different

The between-group comparison using an Independent Sample t-test (Table 3) revealed statistically significant differences in posttest scores between the experimental and control groups. Mathematical literacy scores were significantly higher in the experimental group, $t(46) = 6.45$, $p < .001$, with a large effect size ($d = 1.86$). Numeracy showed the strongest difference, $t(46) = 8.32$, $p < .001$, with a very large effect size ($d = 2.40$). Critical thinking was also significantly higher in the experimental group, $t(46) = 7.21$, $p < .001$, with a large effect size ($d = 2.08$). These findings confirm that students who learned using Prodigy Math Game outperformed those receiving conventional instruction across all three competencies.

Collectively, the statistical results indicate not only significant differences but also substantial practical significance, as reflected by large effect sizes. This suggests that the implementation of Prodigy Math Game produced meaningful improvements in students' mathematical literacy, numeracy, and critical thinking skills beyond conventional instructional approaches.

Discussion

The findings of this study clearly indicate that the implementation of Prodigy Math Game was effective in significantly enhancing students' mathematical literacy, numeracy, and critical thinking skills compared to conventional instruction. The magnitude of improvement, particularly in numeracy and critical thinking, suggests that adaptive digital learning environments can facilitate deeper cognitive engagement. From a theoretical standpoint, these findings support constructivist learning theory, which posits that knowledge is actively constructed through interaction, exploration, and feedback. The game-based environment allowed students to engage in experiential learning, receive immediate corrective responses, and build conceptual understanding through iterative problem-solving processes (Shahini, 2025).

The improvement in mathematical literacy can be explained through the narrative and contextual structure embedded within the game. Prodigy Math Game presents mathematical problems within meaningful scenarios, requiring students to interpret textual information before solving tasks. This aligns with Gee (2007) perspective that digital games foster literacy development by situating reading within purposeful and engaging contexts. Students are not merely decoding text; they are interpreting it to achieve in-game goals. Such contextualization strengthens comprehension skills and promotes the integration of reading and mathematical reasoning.

The substantial gains observed in numeracy are strongly aligned with Vygotsky & Cole (1978) Zone of Proximal Development (ZPD). The adaptive algorithm within Prodigy Math Game continuously adjusts task difficulty according to students' performance levels, thereby functioning as a form of digital scaffolding. By presenting challenges slightly beyond students' current competence while still providing support through feedback mechanisms, the game facilitates optimal cognitive growth. This dynamic adjustment likely explains why numeracy showed the highest improvement among the measured variables, as repeated exposure to progressively calibrated tasks strengthens both procedural fluency and conceptual understanding.

Regarding critical thinking, the findings are consistent with Prensky (2012) argument that digital games promote strategic thinking and problem-solving abilities. Students were required to analyze problems, evaluate possible solution strategies, and reflect on errors when feedback was provided. Unlike traditional instruction, which may emphasize direct procedural explanation, the game environment encouraged independent reasoning and experimentation. This interactive problem-solving structure appears to have fostered reflective thinking processes that are central to higher-order cognitive development.

Another contributing factor to the observed learning gains is increased student motivation and engagement. Based on classroom observations and interviews, students demonstrated higher persistence and enthusiasm during game-based sessions. This finding aligns with Self-Determination Theory (Deci & Ryan, 2013), which posits that intrinsic motivation is enhanced when learners experience autonomy, competence, and relatedness. The adaptive challenges provided a sense of competence, the individualized gameplay supported autonomy, and the interactive environment promoted engagement. Motivation, therefore, likely acted as a mediating factor that strengthened cognitive outcomes (Ke, 2009).

Despite these promising findings, several limitations must be acknowledged. First, the quasi-experimental design lacked random assignment, which limits causal generalization. Second, the sample size was relatively small and drawn from a single school, restricting external validity. Third, the intervention period was limited to four weeks, making it difficult to assess long-term retention effects. Fourth, the possibility of a Hawthorne effect cannot be ruled out, as students in the experimental group may have been influenced by the novelty of using digital technology. Finally, the use of researcher-developed instruments, although validated and tested for reliability, may introduce measurement bias. Future research should employ randomized controlled trials with larger and more diverse samples, extend the duration of intervention to examine long-term impact, and explore differential effects across demographic groups such as gender and prior achievement levels. Additionally, mixed-method approaches are recommended to gain deeper insights into students' cognitive and emotional experiences during digital game-based learning.

However, although research findings demonstrate the effectiveness of Prodigy Math Game, there are several challenges that need to be considered. These include technological device accessibility, teacher readiness in utilizing educational games, and technical constraints such as internet connectivity. A study by Selwyn (2021) revealed that one of the main barriers in educational technology implementation is the digital divide, both in terms of device access and teachers' skills in effectively utilizing these tools. Therefore, the use of technology in learning should be supported by adequate facilities and teacher training to enable proper integration of technology with appropriate teaching methods.

From a practical perspective, the findings suggest that educational stakeholders should consider integrating adaptive digital game-based tools into mathematics instruction as structured pedagogical strategies rather than supplementary entertainment. Teachers should receive professional development on effectively aligning game-based activities with curricular objectives. Schools need to ensure adequate technological infrastructure to support equitable access. Policymakers may consider incorporating adaptive digital learning platforms into broader educational innovation initiatives aimed at strengthening 21st-century competencies.

In conclusion, this study provides empirical evidence that adaptive game-based learning environments can serve as powerful cognitive scaffolding systems that enhance mathematical literacy, numeracy, and critical thinking skills in elementary education Clark et al. (2016). By bridging constructivist pedagogy with digital technology, Prodigy Math Game demonstrates the potential to transform traditional mathematics instruction into a more interactive, reflective, and developmentally responsive learning experience.

D. Conclusions

This study demonstrates that the integration of Prodigy Math Game as an adaptive digital learning tool significantly enhances elementary students' literacy, numeracy, and critical thinking skills compared to conventional instruction, with numeracy showing the most substantial improvement. The findings indicate that interactive problem-solving, immediate feedback, and adaptive task calibration contribute to deeper conceptual and procedural understanding rather than merely increasing student engagement. Theoretically, these results reinforce constructivist learning principles by confirming that active knowledge construction within digital environments promotes meaningful learning, while simultaneously providing empirical support for Vygotsky's Zone of Proximal Development through technology-mediated scaffolding mechanisms. Practically, the study suggests that Prodigy Math Game can function not only as a motivational supplement but as a structured instructional strategy to strengthen 21st-century competencies such as critical thinking and problem-solving in elementary mathematics classrooms. Nevertheless, given the limited sample and intervention duration, future research should involve broader populations, longer implementation periods, and further examination of specific game mechanics to better understand their differentiated impact on various cognitive competencies.

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