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The Influence of the IMC (Interactive Mathematical Conceptualization) Model with Wayground on the Basic Mathematical Abilities of Elementary Madrasah Students

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ABSTRACT

This study aims to examine the effect of the Interactive Mathematical Conceptualization (IMC) model assisted by Web Wayground on the basic mathematical abilities of elementary madrasah students. Utilizing a quasi-experimental approach with a Nonequivalent Control Group design, this study involved 57 fifth-grade students from a single elementary madrasah, assigned to an experimental group (n = 29) and a control group (n = 28). Data were analyzed using Analysis of Covariance (ANCOVA) with pre-test scores as covariates. The results revealed a significant effect of the IMC model on students' basic mathematical abilities, F (1, 54) = 10.326, p = 0.002, with a Partial Eta Squared (η_p^2) of 0.161, indicating a large practical effect size. The experimental group achieved a higher post-test average (82.06) compared to the control group (71.96). The pedagogical novelty lies in repositioning the digital platform as an initial exploration tool and utilizing real-time interaction data for guided conceptualization, which strengthens Cognitive Load Theory and social constructivism. The study recommends integrating the IMC model to enhance basic mathematical abilities in elementary education, suggesting future research investigate higher-order thinking skills through longitudinal designs.

INTRODUCTION

Mathematics is a fundamental discipline that underlies logical reasoning, problem-solving capacities, and subsequent academic achievements in elementary education (Chen, 2025; Hoffmann & Even, 2024; Lovianova et al., 2022). Within the context of elementary madrasahs, a firm mastery of these basic mathematical abilities is paramount for scaffolding more complex concepts in higher grades. However, global assessments continually reveal systemic challenges in this domain. The latest Programme for International Student Assessment (PISA) report indicates that a significant majority of students in developing countries, including Indonesia, perform below the minimum proficiency level in mathematics (OECD, 2023). Locally, this international deficit resonates with the Indonesian National Assessment, where data from the Minimum Competency Assessment (*Asesmen Kompetensi Minimum* (AKM)) shows that more than half of elementary-level students have not attained basic proficiency in mathematical conceptualization (Kemendikbudristek, 2023). This pervasive gap underscores the limitation of conventional, passive pedagogical methods in fostering deep conceptual clarity, thereby driving an urgent need for interactive instructional interventions.

A heavy reliance on conventional, textbook-centered instructional practices largely drives the persistence of low mathematical proficiency in elementary schools (Effendy et al., 2025; Sukmana, 2024). In many primary classrooms, mathematics education is limited to the passive use of printed textbooks and repetitive paper-based question drills (Sholahudin & Oktaviyanthi, 2025). This traditional routine forces students to solve abstract algorithms through continuous rote-drilling without understanding the underlying mathematical concepts (Kania et al., 2023; Kaplar et al., 2022). Furthermore, this approach completely lacks interactive digital media or technology-driven visual scaffolds, leaving students disengaged and struggling to comprehend abstract structures (Abdullah et al., 2025; Rehman et al., 2024). To bridge this pedagogical gap, transitioning from rigid textbook-bound assignments to interactive digital media has become an urgent necessity (Yusupova et al., 2025). Integrating dynamic digital tools can transform static exercises into engaging conceptual explorations, thereby effectively cultivating students' basic mathematical abilities (Kristesia et al., 2025).

To overcome the limitations of rigid, textbook-centric drilling, there is an urgent need for an instructional framework that harmonizes digital interactivity with structured conceptual pedagogy. This study addresses this need by introducing the Interactive Mathematical Conceptualization (IMC) model, a novel pedagogical synthesis designed to transform passive routines into active cognitive exploration. Integrated with the Web Wayground platform, a dynamic digital environment utilizing gamified interfaces, the IMC model operates through three synergistic phases: digital interactive exploration, data-based guided conceptualization leveraging real-time student error analytics, and concept reinforcement through instant feedback (Bygstad et al., 2022). While prior research acknowledges that gamified digital tools can significantly boost student motivation and engagement in mathematics (Yuliani et al., 2025), most existing interventions merely digitize traditional worksheets without offering a structured framework for conceptual reconstruction. The IMC model fills this critical gap by turning immediate digital performance metrics into actionable pedagogical insights, allowing teachers to address misconceptions on the spot.

Therefore, the primary objective of this study is to investigate the empirical influence of the Interactive Mathematical Conceptualization (IMC) model integrated with Web Wayground on the basic mathematical abilities of elementary madrasah students. While conventional, textbook-centered instruction frequently fails to nurture foundational numeracy, this research provides a rigorous evaluation of how real-time digital analytics and structured conceptual pedagogy reshape student learning outcomes. By focusing specifically on fifth-grade students within an Islamic primary school context (*Madrasah Ibtidaiyah*), this study fills a distinct geographical and pedagogical gap in localized educational technology integration (Mishra & Koehler, 2006). Ultimately, the insights gained from this investigation are expected to offer actionable, innovative alternatives for primary educators seeking to transition from passive, paper-based drills to digitally-scaffolded conceptual mathematics.

METHOD

Research Design

This study implemented a quantitative approach with a quasi-experimental research design, specifically employing the pretest-posttest non-equivalent control group design (Creswell, 2018). This design was selected because the operational administration of the madrasah did not allow for the random assignment of individual students into new groups without disrupting the ongoing learning ecosystem. Therefore, pre-existing intact classes were utilized to maintain ecological validity. The structural layout of this research design is organized in Table 1.

Table 1. Quasi-Experimental Research Design Layout

Cohort Group	Pretest	Pedagogical Treatment	Posttest
Experimental Class ($n = 29$)	O_1	IMC framework via Web Wayground (X)	O_2
Control Class ($n = 28$)	O_3	Conventional instruction	O_4

Where $O1$ and $O3$ represent the initial baseline measurements (pretest), X denotes the pedagogical treatment utilizing the IMC model via Web Wayground, the empty notation (–) indicates the use of conventional textbook routines, and $O2$ and $O4$ represent the final assessments (posttest).

Participants and Research Setting

The research was executed at MI Asas Islam Kalibening, located in Salatiga, Central Java. The target population encompassed all fifth-grade students within the institution. At the same time, the sample was selected using purposive cluster sampling based on classroom groups that shared identical academic schedules and baseline capacities. The total participant pool consisted of 57 students. This sample was distributed into two distinct intact cohorts: the Experimental Group (Class 5C, $n = 29$) which engaged with the digital framework, and the Control Group (Class 5B, $n = 28$) which underwent traditional instruction.

Instructional Intervention

The pedagogical intervention was sustained across both groups for a duration of six instructional sessions spanning a total of two weeks, focusing on the mathematical unit of computing whole numbers up to 1 million.

1. Experimental Group: Students were exposed to the Interactive Mathematical Conceptualization (IMC) model powered by Web Wayground. The application operated through three sequential stages: digital interactive exploration, where students manipulated scalable mathematical objects; data-based guided conceptualization, where the instructor used real-time error analytics from the web platform to clarify student misconceptions; and concept reinforcement through instant digital feedback loops.
2. Control Group: Students received instruction via conventional classroom routines. The learning process relied entirely on direct lecturing, physical printed textbooks, and repetitive paper-based question drills, without any integration of interactive digital media.

Research Instrument

The primary tool for data collection was an objective test designed to measure the basic mathematical abilities of the students. The items were structured as multiple-choice, with a correct response receiving a score of 1 and an incorrect response receiving a score of 0. The initial assessment pool consisted of 35 items.

The structural framework of this instrument was directly derived from the official curriculum learning objectives for fifth-grade mathematics, which specifically mandate mastery of whole numbers up to 1 million. To operationalize these institutional learning objectives into measurable test items, the instrument was mapped into four core competency indicators:

1. Identifying and representing the coordinates of place value up to millions.

2. Reading and writing whole numbers up to 1 million in multiple numerical notations.
3. Comparing, ordering, and estimating the actual magnitudes of large numbers.
4. Solving complex arithmetic word problems involving large-scale values.

Instrument Validity and Reliability

To ensure empirical rigor, the initial pool of 35 items underwent a field trial in an equivalent fifth-grade setting before the actual research. Item validity was calculated using the Pearson Product-Moment correlation, and items were retained only if their corrected item-total correlation exceeded the critical threshold of 0.361. Out of the initial pool, 15 items failed to meet the psychometric criteria and were discarded. Consequently, 20 highly valid items were selected for the final instrument. The internal consistency of these 20 final items was evaluated using Cronbach's alpha, yielding a high reliability index of 0.85, which met the acceptance criteria for formal educational testing (Fraenkel et al., 2012).

Data Analysis

The quantitative datasets were processed using both descriptive and inferential statistical modeling. Descriptive statistics were employed to calculate the mean scores, maximum and minimum values, and standard deviations for both cohorts. Before evaluating the primary hypothesis using Analysis of Covariance (ANCOVA), a series of mandatory parametric prerequisite tests were conducted. These checks included the Shapiro-Wilk test for normal distribution, Levene's test for homogeneity of variance, a linearity test, and the verification of the homogeneity of regression slopes (AlAita & Aslam, 2023). The main ANCOVA F test was evaluated at a significance level of alpha 0.05, and the practical magnitude of the pedagogical intervention was quantified using the Partial Eta Squared effect size metric.

RESULTS AND DISCUSSION

The statistical analysis in this study commenced with a descriptive evaluation to capture the students' baseline and post-intervention mathematical competencies. This preliminary assessment focused on fifth-grade students' proficiency in computing with whole numbers up to 1 million.

To provide a clear and immediate visual comparison of the academic progression between the two groups, the distribution of pre-test and post-test scores is illustrated in Figure 1.

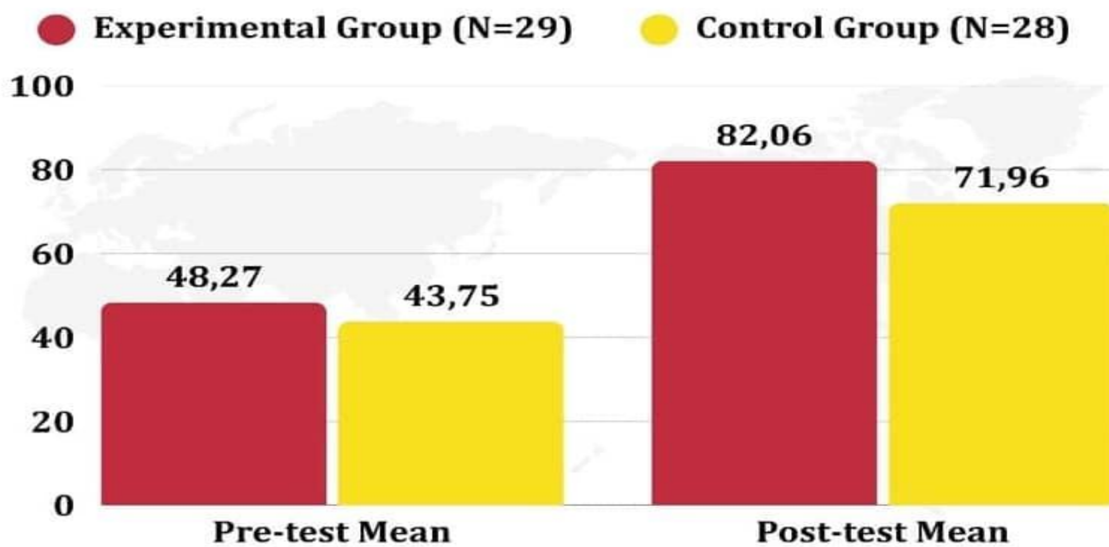

Figure 1. Comparison of Pre-test and Post-test Mean Scores between the Experimental and Control Groups

As illustrated in Figure 1, both classes demonstrated an upward shift in their mathematical conceptualization capabilities. The Experimental Group, utilizing the Interactive Mathematical Conceptualization (IMC) model integrated with Web Wayground, began with an initial pre-test average of 48.27 and advanced to a post-test mean of 82.06, reflecting a descriptive improvement of 33.79 points. Conversely, the Control Group, which engaged with conventional instructional methods, started at a baseline of 43.75 and reached a post-test average of 71.96, indicating a growth of 28.21 points. Although both groups experienced academic progression, the group exposed to the digital pedagogical intervention exhibited a more pronounced descriptive gain.

Prerequisite Assumptions Testing

To determine the appropriate statistical parameters for testing the research hypothesis, mandatory prerequisite analyses consisting of normality and homogeneity tests were executed. The compiled data for these parametric assumptions are structured in Table 2.

Table 2. Normality and Homogeneity Verification Matrix

Statistical Assumption	Assessment Variable	Group Cohort	Statistic Value	Significance (p)	Decision
Normality (Shapiro-Wilk)	Pretest	Experimental	0.948	0.122	Normally Distributed ($p > 0.05$)
		Control	0.959	0.315	Normally Distributed ($p > 0.05$)
	Posttest	Experimental	0.947	0.118	Normally Distributed ($p > 0.05$)
		Control	0.966	0.465	Normally Distributed ($p > 0.05$)
Homogeneity (Levene Test)	Pretest Variances	Combined	$F = 0.462$	0.499	Equal Variances ($p > 0.05$)
	Posttest Variances	Combined	$F = 0.080$	0.779	Equal Variances ($p > 0.05$)

The statistical computations organized in Table 2 confirm that all prerequisite criteria for parametric analysis were successfully fulfilled. The Shapiro-Wilk significance values for all observation vectors were well above the critical threshold of 0.05, indicating that the scores across both groups conformed to a normal distribution. Furthermore, the Levene test yielded significance values of 0.499 for the pretest and 0.779 for the posttest. Because these indices are well above 0.05, the assumption of equal variances across the cohorts was sustained.

Hypothesis Testing via ANCOVA

The primary research hypothesis regarding the empirical impact of the instructional intervention was formally evaluated using a one-way Analysis of Covariance (ANCOVA). The full breakdown of the ANCOVA source matrix is presented in Table 3.

Table 3. ANCOVA Summary for Posttest Mathematical Efficacy

Source of Variance	Sum of Squares	Degrees of Freedom (df)	Mean Square	F-Statistic	Significance (p)	Partial Eta Squared (ηp2)
Corrected Model	1584.238	2	792.119	9.805	0.000	0.266
Intercept	8345.112	1	8345.112	103.298	0.000	0.657
Pretest (Covariate)	137.985	1	137.985	1.708	0.197	0.031
Group (Treatment)	834.195	1	834.195	10.326	0.002	0.161
Error	4362.534	54	80.788			
Total	344250.000	57				
Corrected Total	5946.772	56				

The inferential outputs displayed in Table 3 reveal a statistically significant main effect for the instructional treatment after controlling for the initial baseline discrepancies of the pretest covariate, yielding $F(1,54) = 10.326$, $p = 0.002 < .05$. Because the asymptotic significance level fell safely below the 0.05 alpha boundary, the null hypothesis was rejected. This outcome provides empirical evidence that implementing the IMC model, assisted by Web Wayground, yields a significantly greater effect on students' basic mathematical abilities than traditional textbook routines.

Furthermore, the practical impact of this digital intervention was confirmed by the Partial Eta Squared value ($\eta_p^2 = 0.161$). This index demonstrates that the instructional method alone accounted for approximately 16.1% of the total variance observed in the students' posttest scores. According to standard statistical conventions, an effect size value that surpasses the 0.14 threshold represents a large effect magnitude. This confirms that the IMC framework delivers substantial practical efficacy within the classroom environment, offering a robust alternative for teachers seeking to transition from rote learning to digitally scaffolded mathematics

The empirical evidence generated from the ANCOVA model confirms that the integration of the Interactive Mathematical Conceptualization (IMC) model with Web Wayground yields a significantly higher advancement in the basic mathematical abilities of fifth-grade elementary madrasah students compared to traditional, textbook-bound pedagogical routines. This substantial variance in academic transformation is fundamentally rooted in the structural design of the IMC framework, which systematically replaces passive instruction with active, digitally-scaffolded cognitive engagement. While conventional methods lock students into static, paper-based repetition that often induces cognitive fatigue, the dynamic environment of Web Wayground serves as a fertile pedagogical catalyst that reshapes how abstract mathematical concepts are explored and internalized.

Digital Interactive Exploration via Web Wayground

The profound efficacy of the IMC model is primarily driven by its first operational phase, which is natively facilitated through the Web Wayground platform. In teaching large whole numbers up to 1 million, conventional pedagogy heavily relies on abstract symbolic representation, forcing fifth-grade students to memorize place values without a tangible cognitive anchor. This abstract approach often creates a pedagogical disconnect, given that learners in this age bracket (typically 10–11 years old) are transitioning through the later stages of Piaget's concrete operational cognitive development (Gorman, 2025; Ruamba et al., 2025). In this developmental window, children still require concrete or semi-concrete representations to internalize complex mathematical concepts before they can efficiently process purely symbolic notations (Sarama & Clements, 2026).

The integration of Web Wayground directly resolves this issue by transforming static numbers into dynamic visual manipulatives. Through the platform's interactive interfaces, abstract millions, hundred-thousands, and ten-thousands are visualized as scalable digital objects. This active digital engagement aligns with Mayer's Cognitive Theory of Multimedia Learning, which posits that integrating visual and verbal channels significantly enhances deeper cognitive processing compared to single-mode delivery (Huang et al., 2023; Mayer, 2024).

When students manipulate these digital assets, they receive immediate sensory and visual feedback, allowing them to construct a resilient mental schema of numerical scale and place-value relationships (Bower et al., 2022). This real-time feedback loop drastically reduces extraneous cognitive load, preventing the cognitive fatigue often induced by traditional textbook-bound drills (Sun et al., 2023; Uwineza et al., 2023). Consequently, this initial exploration phase effectively bridges the gap between concrete observation and abstract mathematical reasoning, establishing a secure empirical foundation before student progress to complex arithmetic operations.

Conceptual Internalization and Problem Solving

The second phase of the IMC model, conceptual internalization and problem-solving, marks a critical pedagogical shift from digital manipulation to abstract mathematical application. In this phase, the digital scaffolding provided by Web Wayground is systematically faded, prompting fifth-grade students to internalize the visual schemas developed during the exploration phase and apply them to complex problem-solving contexts involving whole numbers up to 1 million. This transition deeply aligns with Vygotsky's Zone of Proximal Development (ZPD) (Clapper, 2015), where instructional technology acts as a temporary scaffold that enables learners to perform tasks they could not initially achieve independently. As students transition to solving multi-step mathematical problems, the platform transforms from an exploratory playground into a tool for cognitive verification, allowing students to validate their mathematical hypotheses in real time (Gong et al., 2025; Tubera & Limpot, 2025).

Furthermore, mathematical problem solving is not merely a mechanical application of procedures, but a cognitive process requiring deep conceptual understanding and metacognitive monitoring (Schoenfeld, 2021). Traditional mathematical instruction often stifles this process by presenting large-number word problems that require rote algorithmic solutions, which frequently leads to conceptual errors when numbers scale up to millions. In contrast, the IMC framework utilizes Web Wayground to contextualize large numbers within realistic problem-solving scenarios. This contextualization supports authentic learning and fosters self-regulated problem-solving strategies among young learners (Ferreira et al., 2022). By internalizing the mathematical concepts through interactive problem-solving, students in the experimental group demonstrated a higher degree of mathematical proficiency and flexibility, directly accounting for the significantly superior ANCOVA post-test scores observed in this study.

Contrasting the IMC Framework with Conventional Instruction

The statistical disparity revealed by the ANCOVA analysis underscores a profound pedagogical divergence between the IMC framework and conventional instructional models. In the control group, where mathematical concepts were delivered through traditional lecturing methods and drills focused on textbooks, students frequently struggled to grasp the magnitude of numbers approaching 1 million. This limitation stems from the fact that conventional methods heavily emphasize procedural fluency such as memorizing rules of place value at the expense of conceptual understanding (Cowling et al., 2025). Without interactive or visual representations, fifth-grade students often view large numbers as arbitrary strings of digits rather than proportional quantities, leading to a high rate of systematic errors during complex problem-solving tasks.

Conversely, the success of the experimental group demonstrates that integrating Web Wayground within the IMC model fundamentally alters the cognitive landscape of primary mathematics classrooms. By replacing passive reception with active digital manipulation, the IMC model provides a dual coding environment where verbal explanations are instantly paired with visual and dynamic representations (Ruf et al., 2022). This approach prevents the cognitive disengagement that typically occurs when young learners face abstract and large scale arithmetic (Wilkie, 2025). The integration of this model does not merely improve immediate test scores; it reframes how students conceptualize mathematical scales, fostering a deeper mathematical disposition alongside spatial and numerical awareness that traditional direct instruction fails to cultivate. Consequently, this study provides robust empirical evidence that shifting from conventional procedural instruction to technologically scaffolded conceptual models is essential for modern primary mathematics education.

The findings of this study offer significant implications for both theoretical frameworks and practical applications in primary mathematics education. Theoretically, this research enriches the literature on dual coding and cognitive development by demonstrating how digital platforms on the web can successfully bridge the gap between concrete observation and abstract reasoning for fifth-grade students. It proves that technological scaffolding is most effective when it actively transforms mathematical concepts into dynamic objects rather than merely digitizing traditional worksheets.

Practically, this study provides a validated instructional framework for primary school teachers and educators in Islamic institutions. The IMC model combined with Web Wayground offers a concrete solution to the classic problem of student disengagement when facing large numbers. School principals and curriculum designers can utilize these insights to integrate interactive digital media into standard teaching plans, shifting the pedagogical focus from passive memorization to active conceptual visualization.

Despite the positive outcomes demonstrated by the statistical data, several limitations must be acknowledged. First, this research was conducted within a single academic term with a relatively small sample size drawn from one specific primary school. Consequently, the findings may not be immediately generalizable to diverse demographic regions or schools with different levels of technological infrastructure. Second, the scope of this investigation was strictly limited to the topic of whole numbers up to 1 million. Therefore, the efficiency of the IMC model on other complex mathematical topics, such as fractions or spatial geometry, remains untested in this specific context.

To address these limitations, future research should expand implementation of the IMC framework across larger, more diverse student populations, including multi-regional trials to verify its broader scalability. Longitudinal studies are also highly recommended to examine the long-enduring effects of this model on student retention of mathematical concepts over extended periods. Finally, subsequent investigations should explore how the combination of the IMC model and platforms on the web can be adapted to teach other challenging areas of mathematics, ensuring a more comprehensive digital transformation in primary education.

CONCLUSION

In conclusion, this study demonstrates that the Interactive Mathematical Conceptualization model integrated with Web Wayground significantly improves the conceptual understanding and problem-solving abilities of fifth-grade students when learning whole numbers up to 1 million. The empirical evidence from the analysis of covariance confirms that students exposed to this interactive digital framework achieved substantially higher learning outcomes compared to those taught through conventional methods. By transforming abstract mathematical scales into dynamic and visual representations, the proposed model successfully facilitates cognitive internalization and bridges the gap between concrete exploration and formal arithmetic. Ultimately, these findings suggest that shifting away from traditional lecturing toward technologically scaffolded instruction is essential for fostering meaningful mathematical proficiency in modern primary classrooms.

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