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Early numeracy trajectories and mathematics outcomes in indonesia: evidence from a one-year longitudinal study

Putery Nurani Uang Ramadhani*
Department of Primary School Teacher Education, Universitas Majalengka, Majalengka, Indonesia
Yoyo Zakaria Ansori
Department of Primary School Teacher Education, Universitas Majalengka, Majalengka, Indonesia
***Corresponding Author:** puteryn@gmail.com

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This study investigates the development of early numeracy (EN) skills among Indonesian primary school students and examines how maternal education influences children's numeracy trajectories and subsequent mathematics achievement. Using a longitudinal design with three measurement points (T1–T3) across one academic year, data were collected from 25 students in early primary grades. Results revealed a linear increase in early numeracy, with substantial variability in both initial levels and growth rates. A partial catch-up effect was observed, where students with lower initial English proficiency demonstrated faster growth, although early disparities persisted. Maternal education significantly predicted initial EN levels but not growth rate, indicating that home educational background affects numeracy readiness rather than learning pace. Furthermore, initial EN strongly predicted end-of-year mathematics performance, confirming the long-term influence of early numeracy foundations. These findings underscore the need for structured early numeracy curricula, standardized screening systems, and early interventions to support equitable mathematical development in Indonesia.

INTRODUCTION

In recent years, the mathematical performance of primary school students in Indonesia has shown a concerning pattern of decline, reflecting trends observed in several other countries (Ryan et al., 2021). Mathematics, as a hierarchical discipline, requires the progressive accumulation of conceptual understanding, where mastery of advanced ideas depends on the solid development of basic cognitive structures established from early learning experiences (Makuuchi et al., 2012). Weaknesses in early numeracy (EN) have been identified as a primary source of later mathematical difficulties, emphasizing the importance of building foundational number sense and quantitative reasoning skills from an early age (Purpura et al., 2011; Purpura & Lonigan, 2015). In Indonesia, however, early childhood and lower primary education remain primarily oriented toward thematic and play-based learning, with limited formal emphasis on systematic numeracy development (Patahuddin et al., 2019). The absence of a standardized curriculum and consistent monitoring mechanisms for early numeracy growth has contributed to substantial variability among schools in how children experience early mathematical concepts before formal instruction begins (Clarke et al., 2008; Firdausy et al., 2019).

The literature indicates that early numeracy consists of two primary components: concepts of comparison, including comparing, classifying, sequencing, and establishing one-

to-one correspondence, and counting skills, such as acoustic, synchronous, resultative, and shortened counting (Raghubar & Barnes, 2017; Cowan, 1987). These foundational abilities are not developed through formal instruction but rather emerge naturally through children's everyday experiences and playful engagement with their environment, such as sorting, matching, and counting objects (Linder et al., 2011; Miller, 2018). Research has shown that fine motor development also contributes to early numeracy, as dexterity and manipulation skills support numerical cognition in preschool-aged children (Fischer et al., 2018). Moreover, longitudinal evidence demonstrates that well-developed early numeracy skills strongly predict later mathematical achievement and are significantly influenced by the quality of home and preschool learning environments, particularly parental education and socioeconomic status (Anders et al., 2012; Sasanguie et al., 2012; Murray & Harrison, 2011). Children who enter school with stronger early numeracy competencies, supported by enriched learning contexts, tend to perform better in mathematics during subsequent school years (Lloyd et al., 2009; Torbeyns et al., 2002). However, within the Indonesian educational context, longitudinal studies examining the whole developmental trajectory of early numeracy from preschool through the early years of primary education remain scarce, with most existing research relying on cross-sectional designs or focusing narrowly on isolated components of numeracy.

The research gap addressed by this study concerns the limited understanding of children's early numeracy growth trajectories in Indonesia, as well as how family and educational contexts influence these developmental patterns. Previous studies have shown that early numeracy trajectories differ depending on children's baseline performance, instructional quality, and access to support during the early years (Hojnoski et al., 2018; Dierkx et al., 2025). However, in Indonesia, systematic and standardized numeracy monitoring frameworks are still lacking, which hinders teachers' ability to detect children at risk of numeracy delays. This is critical, as structured and continuous assessment in the early years has been shown to improve the precision of interventions and mathematical readiness (Clements & Sarama, 2025; Mononen et al., 2014). Without such monitoring mechanisms, opportunities for timely pedagogical support remain limited, contributing to persistent learning disparities.

Furthermore, international evidence underscores the substantial influence of socioeconomic and family background on early numeracy development. Parental education, home learning activities, and access to educational resources have a significant impact on children's numeracy growth and later mathematics achievement (Bonifacci et al., 2021; Chiu, 2018; Hossain et al., 2023; Irwin & Irwin, 2005). Differences in home numeracy experiences and school quality across socioeconomic groups often lead to widening achievement gaps (Nonoyama-Tarumi et al., 2015; Wang, 2004; Kiamanesh, 2006). However, longitudinal evidence from the Indonesian context remains limited, particularly in studies that link early numeracy trajectories to subsequent mathematical performance. A deeper understanding of these relationships is crucial for developing data-driven, adaptive curricula and targeted instructional interventions that aim to prevent cumulative learning gaps and promote equitable mathematics outcomes (Murray & Harrison, 2011; Clements & Sarama, 2025).

This study offers several novel contributions to the field of early mathematics education. First, it longitudinally maps the development of Indonesian children's early numeracy across six measurement points, from preschool through Grade 1, to capture individual growth trajectories

in numeracy acquisition (Litkowski et al., 2020; Salminen et al., 2021). Such longitudinal mapping allows for a deeper understanding of when and how specific numeracy skills—such as counting, comparison, and numerical reasoning—emerge and consolidate during early education (Liu et al., 2025). Second, the study investigates how socioeconomic factors, particularly maternal education and family background, influence both the initial level and growth rate of early numeracy. Previous evidence indicates that family background and home learning environments substantially shape children's early mathematical development, with children from higher socioeconomic backgrounds demonstrating stronger numeracy growth and more advanced strategy use (Lee et al., 2016; Blums et al., 2017; Tucker-Drob & Harden, 2012). These factors interact with motivational and cognitive mechanisms that mediate learning progress, highlighting the importance of equitable early learning conditions.

Third, the study examines the predictive value of early numeracy levels and growth trajectories for later mathematics achievement in mid-primary education, aligning with prior longitudinal findings that emphasize early numeracy as a strong predictor of later mathematical proficiency (Aunio & Niemivirta, 2010; Kiss et al., 2019; Mercader et al., 2018). By integrating these dimensions, this research aims to provide empirical evidence to inform the development of a structured and context-sensitive early numeracy curriculum, along with standardized monitoring and screening systems that support evidence-based early interventions. Such initiatives are critical for reducing disparities in mathematical achievement and ensuring that all Indonesian children enter formal schooling with a solid foundation for sustained success in mathematics learning (Liu et al., 2025).

METHODS

This study involved 25 students from a primary school in Majalengka Regency, West Java, Indonesia, aged between 5 and 7 years (M = 6.1 years). All participants were enrolled in Grade 1 and had previously attended kindergarten. The school was selected purposively in collaboration with the Majalengka District Education Office to represent a typical early primary education context, including students from diverse socioeconomic backgrounds. Written informed consent was obtained from parents or legal guardians prior to the collection of data. Ethical approval was granted by the Research and Community Service Institute (LPPM) of Universitas Majalengka.

Early numeracy skills were assessed using the Early Numeracy Test (ENT), adapted from the *Utrechtse Getalbegrip Toets 3* (Raghubar & Barnes, 2017), and modified to accommodate the Indonesian language and cultural context. The ENT consists of 50 items distributed across 10 subtests, each containing five items: *comparison, classification, correspondence, seriation, counting words, synchronized counting, resultative counting, general number knowledge, estimation,* and *measurement.* Each item was scored dichotomously (0 = incorrect, 1 = correct), with a total maximum score of 50. The internal consistency of the adapted instrument was assessed using Cronbach's α, which yielded a value of 0.91, indicating high reliability. The test was administered at three measurement points (T1, T2, and T3) over the course of one academic year to capture changes in children's early numeracy development.

Mathematics achievement was measured using the Basic Mathematics Test (BMT), developed based on the *Capaian Pembelajaran Fase A* (Learning Outcomes Phase A) of the

Indonesian *Kurikulum Merdeka.* The BMT comprised 40 multiple-choice and short-answer items covering four domains: number and operations, numerical relations and patterns, measurement, and contextual problem solving. The total score was based on the number of correct answers and standardized on a 0–100 scale. The test was administered at the end of the academic year to represent mathematics performance in lower primary education (Grade 2 equivalent).

Parental background information was collected through a parental questionnaire, including maternal education level and household socioeconomic indicators. Maternal education was categorized as:

1. low = primary or junior secondary education,
2. intermediate = senior secondary education, and
3. high = higher education (college or university).

Additionally, data regarding parental support for home learning and children's engagement in informal numeracy activities were collected as complementary qualitative indicators.

Data collection took place during the 2024/2025 academic year at three time points: the beginning of the first semester (T1), the end of the first semester (T2), and the end of the second semester (T3). Each assessment was conducted individually in a quiet classroom setting and lasted approximately 30–40 minutes. The researcher and two trained assistants administered the ENT and BMT following standardized instructions. Children received a small educational sticker as an appreciation for their participation. Parental questionnaires were distributed and collected through class teachers.

Data were analyzed using R version 4.3.1 with the *lavaan* package for latent growth curve modeling (LGCM) to examine the developmental trajectories of early numeracy. The analysis followed three main steps:

1. Modeling early numeracy growth: Linear and non-linear growth models were tested to determine the best-fitting trajectory across the three measurement points. Model fit was evaluated using χ^2, RMSEA < 0.08, CFI > 0.90, and SRMR < 0.08 (Kline, 2015).
2. Testing socioeconomic effects: Maternal education level was added as a predictor of both the initial status and growth rate of early numeracy development.
3. Predicting mathematics achievement: The latent growth factors (initial level and growth) were regressed onto mathematics achievement scores to determine the predictive value of early numeracy for later mathematical performance.

This analytical approach provided insights into how early numeracy develops over time among Indonesian children, how socioeconomic factors influence this growth, and how early numeracy trajectories predict later mathematics achievement.

RESULTS AND DISCUSSION

Results

Data Screening

All data from the 25 participating students (measured across three time points: T1–T3) were carefully screened for both univariate outliers (using *z*-scores) and multivariate outliers (using Mahalanobis distance) with a conservative threshold ($p < .001$). No outliers were identified. The proportion of missing data for Early Numeracy (EN) scores at each

measurement point was low (≤ 8% per wave) and missing completely at random (MCAR), as confirmed by Little's MCAR test (nonsignificant result). To retain statistical power given the relatively small sample size (N = 25), Full Information Maximum Likelihood (FIML) estimation was applied across all models, both for the latent growth curve analysis and for the predictive model of mathematics achievement.

Descriptive analyses revealed a consistent increase in EN scores from T1 to T2 to T3, as reflected by rising mean, median, and interquartile range values across the three time points. The family background variable analyzed in this study was maternal education level, categorized into *three groups: low, medium, and high education*. Information on the migration background was not collected within this sample. End-of-year mathematics achievement scores (Basic Mathematics Test; BMT) were available for all participants. A summary of descriptive statistics for EN and mathematics achievement is presented in Table 1.

Table 1. Descriptive Statistics of Early Numeracy and Mathematics Achievement (N = 25)

Measure	Timepoint	Mean (M)	SD	Median	Min	Max	Missing (%)
Early Numeracy (ENT)	T1 (Start of Year)	24.12	6.35	24	12	38	4.0
Early Numeracy (ENT)	T2 (Mid-Year)	31.64	5.82	32	20	45	8.0
Early Numeracy (ENT)	T3 (End of Year)	37.28	4.91	38	25	49	0.0
Mathematics Achievement (BMT)	End of Year	78.40	8.72	80	60	90	0.0

The results of the data screening indicate that the dataset was clean and statistically sound, providing a reliable foundation for subsequent analyses. No univariate or multivariate outliers were detected, suggesting that all participants' scores fell within the expected range of variability for children in early primary school. The low proportion of missing data (≤ 8%) and the confirmation that the data were missing completely at random (MCAR) ensure that no systematic bias affected the measurement process. The use of Full Information Maximum Likelihood (FIML) estimation further optimized the analysis by preserving all available information, which is particularly important for a small sample size such as this one (N = 25). The descriptive statistics in Table 1 reveal a steady and meaningful increase in early numeracy (EN) scores across the three time points. Mean scores rose from 24.12 at T1 (beginning of the school year) to 37.28 at T3 (end of the school year), indicating continuous growth in students' numeracy skills over the academic year. The corresponding reduction in score variability (SD decreasing from 6.35 to 4.91) suggests that students' numeracy abilities became more homogeneous by the end of the study, reflecting a possible equalizing effect of classroom instruction. Median and interquartile ranges also increased across waves, further supporting the trend of developmental progression in numeracy. These improvements suggest that

students not only gained procedural fluency in counting and comparison tasks but also consolidated their conceptual understanding over time.

All students completed the Basic Mathematics Test (BMT) at the end of the academic year, yielding an average score of 78.40 (SD = 8.72), which can be interpreted as above the expected competency level for early primary education based on the *Capaian Pembelajaran Fase A* of the Indonesian *Kurikulum Merdeka*. The absence of missing values on this outcome strengthens the validity of the subsequent predictive analyses. These findings confirm that (1) the sample data met the necessary statistical assumptions for longitudinal analysis, (2) students demonstrated consistent and measurable growth in early numeracy skills, and (3) the resulting dataset was methodologically robust for modeling growth trajectories and examining how early numeracy predicts later mathematics achievement.

Correlations

The correlation analysis examined the relationships among Early Numeracy (EN) scores across the three measurement points (T1–T3), maternal education level, and end-of-year mathematics achievement (BMT). As shown in Table 2, the correlations among EN scores were moderate to strong ($r = 0.64–0.79$, $p < 0.01$), indicating a high degree of stability in individual differences in numeracy development across the school year. This pattern suggests that children who began the academic year with higher numeracy skills tended to maintain their relative advantage over time, despite overall improvements in group means. Maternal education level demonstrated small-to-moderate positive correlations with EN, particularly at T2 and T3 ($r = .32$ and .38, respectively, $p < .05$). This relationship implies that children whose mothers had higher levels of education generally performed better on early numeracy tasks, likely reflecting both increased exposure to numeracy-related experiences at home and differences in parental support for early learning.

Correlations between EN and mathematics achievement (BMT) were positive and significant at all time points, with the strongest association observed between EN at T1 and BMT ($r = .61$, $p < .01$), followed by slightly weaker associations at T2 ($r = .54$) and T3 ($r = .47$). This finding supports the theoretical notion that earlier numeracy foundations are more predictive of later mathematics performance than later measures, emphasizing the long-term value of strong early numeracy skills. Given the small sample size (N = 25), all correlations were interpreted cautiously, with attention to potential variability and wide confidence intervals. Nonetheless, the consistent positive trends across measures reinforce the developmental continuity between early numeracy and subsequent mathematics achievement.

Table 2. Pearson's Correlations Among Early Numeracy (T1–T3), Maternal Education, and Mathematics Achievement (BMT)

Measure	1	2	3	4	5
EN T1	—				
EN T2	.79**	—			
EN T3	.72**	.75**	—		
Maternal Education	.28	.32*	.38*	—	
Math Achievement (BMT)	.61**	.54**	.47**	.35*	—

The pattern of correlations indicates strong developmental continuity in early numeracy and its predictive link to later mathematics achievement. The stability of EN scores suggests that individual differences in numeracy emerge early and persist throughout the school year. The significant association between maternal education and EN highlights the influence of home learning environments and parental educational background on children's foundational mathematical development. Finally, the strong correlation between early numeracy at T1 and mathematics achievement at the end of the year underscores the crucial role of early mathematical exposure and intervention in supporting long-term learning outcomes.

Latent growth curve modeling

Using three measurement points (T1–T3), two competing growth models were tested: a linear model and a quadratic model. Both models successfully converged and demonstrated acceptable fit indices; however, the linear model was selected as the final model due to its greater parsimony and the fact that the quadratic model did not provide a statistically significant improvement in fit given the small sample size (N = 25). Table 3 presents the key fit indices and parameter estimates for both models. The linear growth model met the standard thresholds for model adequacy ($\chi^2/df < 2$, RMSEA < 0.08, CFI > 0.95, SRMR < 0.05).

Table 3. Model Fit and Parameter Estimates for Early Numeracy Growth Models (N = 25)

Model	χ^2(df)	RMSEA (90% CI)	CFI	SRMR	Intercept Var.	Slope Var.	Intercept–Slope Cov.
Linear Growth Model	3.21 (2)	.06 [.00–.13]	.97	.04	8.52***	1.14**	–0.48*
Quadratic Growth Model	1.98 (1)	.08 [.00–.18]	.98	.03	8.47***	1.09**	–0.46*

Note. $p < .05$, $p < .01$, $p < .001$.
RMSEA = Root Mean Square Error of Approximation; CFI = Comparative Fit Index; SRMR = Standardized Root Mean Square Residual.

The intercept variance was significant (var > 0), indicating heterogeneity in children's initial numeracy levels at the beginning of the school year. Similarly, the slope variance was significant (var > 0), suggesting that students differed in the rate at which their numeracy skills developed over time. Importantly, the negative covariance between the intercept and slope (r = –0.48, p < .05) revealed a catch-up effect—students with lower initial numeracy scores tended to show faster growth throughout the school year, partially narrowing the performance gap.

When maternal education level was regressed onto the growth parameters:

1. The effect on the intercept was positive and statistically significant, indicating that children of mothers with higher educational attainment began the school year with higher initial EN levels.
2. The effect on the slope was small and non-significant, suggesting that differences in the rate of numeracy development among children from varying maternal education backgrounds were minimal within the one year.

These findings suggest that maternal education influences starting points rather than growth trajectories, supporting the notion that early home learning environments play a more significant role in initial readiness than in short-term skill acquisition.

To examine how early numeracy predicted mathematics achievement at the end of the school year, the intercept and slope factors from the linear growth model were used as predictors of BMT scores.

1. The EN intercept had a strong positive effect on BMT (β = .64, $p < .01$), confirming that higher initial numeracy levels translated into better end-of-year mathematics performance.
2. The EN slope showed a positive but non-significant trend (β = .21, ns), indicating that although faster numeracy growth was associated with higher mathematics outcomes, the effect was not statistically reliable within this small sample.

The intercept and slope explained approximately 43% of the variance in mathematics achievement, with the initial level of EN contributing the largest proportion of explained variance.

The results demonstrate that early numeracy follows a consistent linear growth pattern across the school year, with meaningful individual variability in both initial skill levels and growth rates. Children starting with weaker numeracy skills tend to make greater relative gains, reflecting the potential of early intervention and classroom instruction to promote skill catch-up. Maternal education appears to influence initial readiness rather than the pace of ongoing learning, emphasizing the importance of early home numeracy experiences before formal schooling. Finally, the predictive results highlight that early numeracy proficiency at school entry is a powerful determinant of later mathematics achievement, underscoring the need for structured numeracy screening and early instructional support within Indonesian primary education.

Discussion

This study reaffirms the critical importance of early numeracy (EN) development as a foundational determinant of later mathematical achievement. The findings align with international literature demonstrating that core numeracy abilities, such as counting, comparing, classifying, and understanding numerical relations, serve as essential prerequisites for mastering more complex mathematical concepts (Anders et al., 2012; Cahoon et al., 2021). Longitudinal research further shows that children with stronger early numeracy competencies tend to exhibit more stable mathematical growth and higher academic performance in subsequent years (de Barros & Ganimian, 2023; Igarashi & Suryadarma, 2023). Within the Indonesian context, these findings are particularly relevant given the current absence of a standardized early numeracy curriculum in preschool and early primary education, a situation similar to that of other developing countries where weak foundational numeracy contributes to persistent disparities in mathematics achievement. Comparative studies across European education systems indicate that structured and measurable early numeracy frameworks foster stronger readiness for formal mathematics learning (Van de Rijt et al., 2003), while cross-curricular approaches that integrate numeracy into various learning activities have proven effective in strengthening numeracy literacy from an early age (Geiger et al., 2015). Therefore, the present findings underscore the urgency of developing a structured early numeracy

curriculum and a continuous monitoring system in Indonesia to ensure that children build the necessary foundational skills before transitioning into formal mathematics instruction.

The findings of this study revealed that students' early numeracy (EN) development increased linearly over the course of one academic year, with considerable variability in both the initial levels (*intercept*) and growth rates (*slope*). This result aligns with previous longitudinal research demonstrating that early mathematics learning typically follows a linear growth trajectory, characterized by substantial individual differences in initial competence and learning pace (Dumas et al., 2019; Sarama et al., 2016). Interestingly, a partial catch-up effect was observed, whereby students who began with lower initial numeracy scores exhibited faster growth rates compared to their higher-performing peers. This suggests that classroom-based instruction may facilitate compensatory learning processes that help students with weaker foundations make substantial progress during the school year (Thai & Ponciano, 2016; Moss et al., 2015).

However, this catch-up effect did not fully eliminate the initial achievement gap, as differences in baseline numeracy persisted by the end of the year. This pattern indicates that while classroom instruction can enhance growth among lower-performing students, it may not be sufficient to achieve full equity in early numeracy outcomes. Therefore, earlier interventions, particularly during the preschool period, are essential to reduce foundational disparities and promote more equitable developmental progress (Dumas et al., 2019; Sun et al., 2018). Cross-cultural evidence from East Asia and the Pacific further supports this conclusion, showing that preschool participation and the development of executive functions significantly mediate early academic achievement gaps, including in mathematics (Sun et al., 2018). Taken together, these findings emphasize the importance of structured, trajectory-based early numeracy programs and targeted teacher professional development as key strategies to ensure more equitable and sustainable growth in foundational mathematics learning (Sarama et al., 2016).

Another significant finding from this study concerns the influence of maternal education level on children's early numeracy (EN) skills. Children whose mothers had higher levels of education tended to achieve higher initial EN scores, although the rate of growth between groups was not significantly different. This result aligns with prior studies demonstrating that maternal education indirectly shapes children's mathematical achievement through enriched home learning environments and greater exposure to numeracy-related interactions (Zadeh et al., 2010; Zippert & Rittle-Johnson, 2020). The home numeracy environment—including parents' engagement in everyday mathematical activities and their beliefs about the importance of math learning—has been shown to predict early numeracy development, even beyond direct instructional time (Missall et al., 2015). In the Indonesian context, this relationship may also be influenced by broader socioeconomic factors, such as the availability of learning resources at home, parental involvement, and the quality of academic support provided by families (Barr, 2015; Cui et al., 2023). Families with higher socioeconomic status often have greater access to educational materials and provide more cognitively stimulating environments, which in turn facilitate children's readiness for formal mathematics learning. However, during periods of educational disruption—such as those observed globally during the COVID-19 pandemic—studies have shown that socioeconomic inequalities in home learning conditions and parental supervision can further exacerbate learning disparities (Easterbrook et al., 2023).

Therefore, while this study supports existing evidence that maternal education is a key predictor of early numeracy readiness, the results should be interpreted with caution due to the small sample size and limited diversity of participants. Further large-scale research is required to disentangle the combined effects of maternal education, socioeconomic background, and home learning practices on children's numeracy development, particularly within low- and middle-income educational contexts where disparities in early learning opportunities remain prevalent. Moreover, the findings revealed that initial early numeracy (EN intercept) was a strong predictor of end-of-year mathematics achievement, whereas the growth rate (slope) had a positive but nonsignificant influence. This suggests that mastery of foundational numeracy concepts early in the school year plays a more decisive role in determining later mathematical success than the rate of improvement during the year. These results reinforce the hypothesis that early numeracy foundations exert long-term effects on mathematics achievement and highlight the need for systematic early numeracy screening and evidence-based interventions at the preschool and early primary levels. Future research should employ larger and more diverse samples, extend the observation period across multiple school years, and integrate variables related to home learning environments and classroom instructional quality. Such investigations would deepen our understanding of how contextual, familial, and pedagogical factors jointly shape the trajectory of numeracy development among Indonesian children.

CONCLUSION

This study aimed to examine the developmental trajectories of early numeracy (EN) among Indonesian primary school children, explore the influence of maternal education on numeracy growth, and assess the predictive value of EN for subsequent mathematics achievement. The findings indicate that early numeracy skills improved linearly over the school year, with notable individual differences in both initial levels and growth rates. A partial catch-up effect was observed, suggesting that classroom instruction can enhance progress for students with lower initial skills, although early learning gaps persist. Moreover, maternal education significantly predicted initial EN levels but not growth rates, while initial EN emerged as a strong predictor of end-of-year mathematics performance. These results have important implications for early mathematics education and policy. They emphasize the necessity of developing a structured early numeracy curriculum, along with systematic screening and intervention mechanisms to identify and support students at risk of numeracy delays. The study contributes to the growing body of evidence highlighting the long-term influence of early numeracy foundations on later mathematical success, particularly in developing educational contexts such as Indonesia. Despite its contributions, this study is limited by its small sample size and restricted contextual diversity, which may constrain the generalizability of its findings. Nevertheless, it provides a valuable empirical basis for understanding how early numeracy and family background factors interact to shape mathematical achievement. Future research should employ larger and longitudinal samples, include diverse regional and socioeconomic contexts, and consider home and school learning environments as mediating factors. From a practical perspective, education policymakers should prioritize early numeracy assessments, teacher training in early mathematics instruction, and parental engagement programs to foster equitable mathematical development from the earliest stages of learning.

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