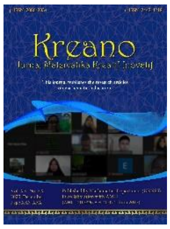
UNNES JOURNALS

Kreano, Jurnal Matematika Kreatif-Inovatif
Volume 17, number 1, 2026, pp. 124-142



Early Numeracy Skills as Predictors of Numeracy Assessment Performance: A Mixed-Methods Study Using the Early Grade Mathematics Assessment Framework

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Abstract

The 2018 PISA results show that Indonesian students' numeracy score is 379, far below the OECD average of 489. This score places Indonesian students' numeracy skills at the lower level (level 1 out of 6) where students are still far from the minimum competency level required to participate in modern society. Meanwhile, students' early numeracy skills are the foundation for further numeracy skills. Therefore, this study aims to analyze the influence of early numeracy skills on the minimum numeracy competency assessment and examine how children's thinking processes in understanding numeracy concepts that are given using the Early Grade Mathematics Assessment framework. This study uses the explanatory sequential mixed method design. A total of 18 second-grade students of SDN 218/IV Jambi City participated in the early numeracy assessment using the Early Grade Mathematics Assessment (EGMA) instrument and the numeracy Minimum Competency Assessment (MCA/AKM) phase A instrument. The linear regression results showed that early numeracy skills significantly influenced the results of the numeracy MCA ($p=0.039$) with a moderate contribution of 24.1%. Through in-depth interviews and observation, information was obtained that family involvement, the use of concrete objects, and counting strategies using physical methods have an important role in shaping children's numeracy skills. Integration of these findings emphasizes the importance of strengthening early numeracy skills with a concrete operational approach and the role of the learning environment in strengthening the numeracy skills of early grade students in elementary school.

Keywords: early numeracy; AKM numeracy; EGMA; regression; explanatory sequential design.

Information of Article

Subject classification	*97C40 Assessment (large scale assessment, validity, reliability, etc.)*
Submitted	*30 September 2025*
Review Start	*6 December 2025*
Round 1 Finish	*19 January 2026*
Round 2 Finish	*13 February 2026*
Accepted	*9 March 2026*
Scheduled online	*30 June 2026*
Similarity Check	*12%*

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Abstrak

Hasil PISA 2018 menunjukkan skor numerasi peserta didik Indonesia sebesar 379, berada jauh di bawah rata-rata OECD sebesar 489. Skor ini menempatkan kemampuan numerasi peserta didik Indonesia pada level bawah (level 1 dari 6) dimana peserta didik masih jauh dari tingkat kompetensi minimum yang diperlukan untuk berpartisipasi dalam masyarakat modern. Sementara, kemampuan numerasi awal peserta didik merupakan fondasi bagi keterampilan numerasi lebih lanjut. Oleh karena itu, penelitian ini bertujuan untuk menganalisis pengaruh kemampuan numerasi awal terhadap hasil asesmen kompetensi minimum numerasi dan menelaah bagaimana proses berpikir anak dalam memahami konsep numerasi yang diberikan menggunakan kerangka Early Grade Mathematics Assessment. Penelitian ini menggunakan metode explanatory sequential design. Sebanyak 18 peserta didik kelas II SDN 218/IV Kota Jambi mengikuti asesmen kemampuan numerasi awal menggunakan instrumen Early Grade Mathematics Assessment (EGMA) dan instrumen Asesmen Kompetensi Minimum (AKM) fase A. Hasil regresi menunjukkan kemampuan numerasi awal berpengaruh secara signifikan terhadap hasil AKM numerasi (p=0,039) dengan kontribusi moderat sebesar 24,1%. Melalui wawancara mendalam diperoleh informasi bahwa keterlibatan keluarga, penggunaan benda konkret, serta strategi berhitung menggunakan metode fisik memiliki peran penting dalam membentuk kemampuan numerasi anak. Integrasi kedua temuan ini menegaskan pentingnya penguatan kemampuan numerasi awal dengan pendekatan operasional konkret dan peran lingkungan sekitar untuk memperkuat kemampuan numerasi peserta didik kelas awal di sekolah dasar.

INTRODUCTION

Numeracy is an essential competency in mathematics learning. Numeracy is the ability to understand and use numerical operation (McIntosh et al., 1992). However, many Indonesian students have not yet achieved the minimum level of numeracy competence expected by OECD standards. The results of PISA 2018 showed that Indonesian students' numeracy score was 379, while the average numeracy score of OECD member countries participating in PISA was 489. Perbedaan skor numerasi sebanyak 110 ini menempatkan skor numerasi Indonesia pada urutan 73 dari 79 negara. This 110-point gap placed Indonesia 73rd among 79 participating countries and indicated that Indonesian students were generally able to solve only numeracy problems involving simple mathematical representations (OECD, 2019).

These data are consistent with previous studies showing that among 308 sixth-grade students in Indonesia, only 8.12% demonstrated good numeracy skills, while 60.71% exhibited moderate to severe misconceptions in numeracy concepts (Yang & Sianturi, 2021). Similar concerns were reflected in the 2022 National Assessment results, which revealed that fewer than 50% of elementary school students achieved the minimum competency standard in numeracy (Kemdikbudristek RI, 2022). This condition indicates that weak numeracy skills among students occur from the elementary school level.

Early numeracy is very important in supporting students' academic success at higher educational levels (Duncan et al., 2007), and even contributes to a country's development index (Hanushek & Woessmann, 2008). This perspective is reinforced by evidence demonstrating that mathematics and reading competencies at the age of seven significantly influence socioeconomic attainment at the age of forty-two (Ritchie & Bates, 2013). Early numeracy is a foundational competency that serves as a strong predictor of children's future mathematics achievement (Andrews & Sayers, 2015). However, empirical evidence indicates that Indonesian students continue to demonstrate limited early numeracy skills. Students frequently struggle to interpret mathematical information presented in various forms (Latifah et al., 2024) and often encounter difficulties understanding contextual problems, even when these are closely related to everyday situations (Pratiwi et al., 2023).

A meta-analysis examining six predictors of student achievement across longitudinal studies conducted in the United States, the United Kingdom, and Canada identified early numeracy as the strongest predictor of academic performance in Grades 3 and 5, surpassing early literacy, attention skills, socio-emotional behavior, general cognitive abilities, and physical health (Duncan & Magnuson, 2011). Early numeracy encompasses six fundamental competencies associated with Early Number Sense (ENS) (Whitacre et al., 2020). Mathematical skills included in early numeracy consist of number recognition, counting, recognizing number patterns, comparing numbers, number operations, and estimation (Sayers et al., 2016). Nevertheless, evidence from Indonesia suggests that students' mathematical competencies remain concentrated on basic arithmetic operations, while skills involving pattern recognition, complex operations, and word problems remain underdeveloped (Bima et al., 2023; Sukandi, 2019).

Meanwhile, the Minimum Competency Assessment (AKM) is an educational system evaluation program designed to map the quality of student learning outcomes at the elementary and secondary education levels in Indonesia (Tim Substansi Asesmen Akademik, 2021, 2023). Unlike traditional assessments that focus primarily on content mastery, AKM emphasizes students' numeracy literacy and their ability to apply mathematical concepts in real-life situations (Rohim et al., 2021). AKM measures competencies across four domains: numbers, geometry and measurement, algebra, and data and uncertainty (Purnamasari et al., 2023). SoAKM items developed according to the recommendations of the Center for Educational Assessment (Pusmenjar) contain personal, socio-cultural, and scientific contexts (Amelia et al., 2023). Furthermore, the cognitive processes assessed include locating information, interpreting and integrating information, and evaluating and reflecting on mathematical data (Tim Substansi Asesmen Akademik, 2021). National AKM results indicate that numeracy achievement among elementary school students remains below the desired competency standards, with fewer than 70% of students reaching the minimum level of numeracy proficiency despite gradual annual improvements (BSKAP, 2023, 2024, 2025).

This condition also occurs at SDN 218/IV Jambi City. Based on the 2022 Education Report Card, the numeracy score of students at SDN 218/IV Jambi City was 1.45 on a scale of 1–3. This indicates that less than 50% of students had achieved minimum competency in numeracy (Kemdikbudristek RI, 2022). Similar conditions have also been found in other elementary schools with low numeracy achievement (Tresnasih et al., 2022), although several schools have already reached the minimum standard (Nurwahidah et al., 2023). Research on learning in the early grades shows that basic numeracy and literacy skills acquired from an early age play a crucial role in determining learning success at higher educational levels; therefore, assessments capable of capturing children's authentic thinking processes are needed (Gove et al., 2013). his fact raises questions regarding the extent to which early numeracy skills influence students' numeracy AKM results and how early-grade students understand the numeracy concepts presented using the Early Grade Mathematics Assessment framework.

Although numerous international

studies have highlighted the importance of early numeracy as a predictor of later mathematical achievement, empirical evidence from Indonesia remains limited. Research in Indonesia that directly links early numeracy skills measured using standardized instruments such as the Early Grade Mathematics Assessment (EGMA) with numeracy achievement measured using the Minimum Competency Assessment (AKM) instrument through a mixed-methods approach in the early grades remains scarce. This research gap serves as the basis for conducting this study. Therefore, the findings are expected to provide a new contribution to understanding the relationship between early numeracy skills and students' numeracy achievement measured using national assessment instruments such as AKM and the Academic Ability Test (TKA) within the context of basic education in Indonesia

Based on this background, the study aims to: (1) analyze the influence of early numeracy skills on the numeracy Minimum Competency Assessment outcomes of second-grade students at SDN 218/IV Jambi City, and (2) examine the factors influencing the numeracy skills of second-grade students at SDN 218/IV Jambi City. To address the first objective, the hypotheses to be tested through the quantitative phase are (1) Null Hypothesis (H_0): there is no significant effect of early numeracy skills on numeracy AKM outcomes, (2) Alternative Hypothesis (H_1): There is no significant effect of early numeracy skills on numeracy AKM outcomes. For the second objective, the research question to be answered through the qualitative phase is how do second-grade students at SDN 218/IV Jambi City think about and understand early numeracy concepts within the EGMA framework.

METHOD

This study employed a basic mixed-method approach with an explanatory sequential design. This design began with the collection and analysis of quantitative data, followed by the collection and analysis of qualitative data to explain the quantitative results (J. W. Creswell, 2015). The quantitative data collected in the first phase consisted of early numeracy scores obtained using the EGMA instrument and numeracy scores obtained using the Phase A AKM instrument. After the quantitative data were collected and analyzed, the results were interpreted to determine the focus of qualitative data exploration in the second phase. The qualitative data collected in the second phase consisted of interview transcripts as the primary data and observation notes as supporting data. The research design is presented in Figure 1.

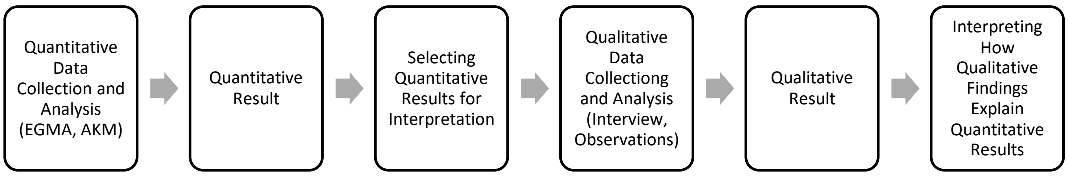


Figure 1. Research Design

The sample in the quantitative phase was selected using the total sampling method, involving the entire population of 18 second-grade students at SDN 218/IV Jambi City as the research sample (Sugiyono, 2019). The use of total sampling was based on the limited population of second-grade students at SDN 218/IV Jambi City, which consisted of only 18 students during the data collection period. In the qualitative phase, participants were selected purposively from the 18 students who participated in the quantitative data collection during the first phase. The selection of qualitative research subjects considered the scores obtained on the EGMA assessment, scores above the average, and the counting strategies used during the EGMA test in accordance with the phenomenon under investigation. This participant selection followed the purposive sampling approach as described by Sugiyono (2019), in which participants are selected because they are able to provide in-depth information relevant to the phenomenon being studied. The inclusion of additional subjects after the in-depth interview with the first subject did not yield any substantial new information. This condition indicated that data saturation had been reached with the first subject. Therefore, the qualitative data analysis was based on the interview and observation results of the first research subject.

The quantitative instruments used in this study were: (1) the Early Grade Mathematics Assessment (EGMA), consisting of the subtests of number identification, number comparison, number patterns, addition, subtraction, and word problems (Platas et al., 2016; RTI International, 2013, 2014), in which the addition and subtraction subtests were divided into Level 1 and Level 2; and (2) the Phase A Numeracy Minimum Competency Assessment (AKM) items released by the Center for Assessment and Learning, Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia, covering three main content areas, namely numbers, algebra, and geometry, in accordance with the numeracy content domains in the national assessment (Tim Substansi Asesmen Akademik, 2021, 2023).

The qualitative instrument consisted of a semi-structured interview guide developed based on the early numeracy indicators in EGMA and adjusted to the objectives of the study. This guide was then reviewed by expert validators, namely lecturers in mathematics education and research methodology, to ensure content validity, language clarity, and contextual suitability for the research subjects. Observations were conducted to examine how students completed the numeracy tasks provided using the EGMA framework, in order to investigate whether students used strategies such as counting with their fingers, using concrete objects, writing with paper and pencil, or solving problems mentally through mental arithmetic.

This study used the Early Grade Mathematics Assessment (EGMA) instrument developed by RTI International, which has undergone scientific validity and reliability testing. Therefore, this study assumed that the EGMA instrument was appropriate for use without revalidation, as is commonly practiced in studies using standardized instruments because it has been widely used across countries and elementary education contexts. In addition, this study used the Phase A Numeracy AKM instrument developed by the Center for Assessment and Learning, Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia. This instrument had undergone internal development and validation processes and has been widely implemented. Therefore, this study assumed that the AKM instrument was valid and reliable and could be used without further instrument testing.

The quantitative data in this study were analyzed using simple linear regression to examine the effect of early numeracy skills on numeracy AKM results. Before conducting the regression analysis, classical assumption tests were performed, including tests of normality, linearity, multicollinearity, and heteroscedasticity. This procedure was consistent with the multivariate statistical analysis approach (Ghozali, 2018; Rinaldi et al., 2020).

The qualitative data in this study were analyzed using thematic analysis by identifying the main themes emerging from the interview transcripts (Braun & Clarke, 2006, 2012). The analysis process was carried out through the stages of data reduction, data display, and conclusion drawing in an iterative manner, meaning repeatedly and gradually, with the aim of refining, improving, and adjusting the findings until the identified themes became sufficiently robust (Creswell, 2015). Validation of the qualitative findings was conducted through triangulation techniques (Sugiyono, 2019), by comparing the interview findings with observation results and strengthening them with student work artifacts.

Furthermore, the integration of quantitative and qualitative findings was conducted at the interpretation stage (Creswell & Creswell, 2018), to enrich the understanding of the relationship between early numeracy and numeracy AKM results. In this research design, the qualitative findings served to explain the statistical results obtained from the quantitative analysis. Thus, this integration allows the research findings to be interpreted more comprehensively and contextually, not only in terms of the magnitude of the statistical effect but also in relation to the underlying cognitive processes.

RESULT AND DISCUSSION

Results

Quantitative Result

Quantitative data were collected to determine the extent to which early numeracy influenced numeracy AKM results. The collected quantitative data were then analyzed using simple linear regression, with early numeracy as the predictor and numeracy AKM results as the dependent variable. Before conducting the simple linear regression analysis, classical assumption tests were first performed to ensure the appropriateness of the regression model used, with the following results.

Normality Test

The normality test was conducted to determine whether the residual data from the regression model were normally distributed. This test used the Kolmogorov–Smirnov Test, which produced a significance value (Asymp. Sig. 2-tailed) of 0.200 ($p > 0.05$), indicating that there was no significant difference between the residual data distribution and the normal distribution. This result shows that the residuals were normally distributed; therefore, the regression model satisfied the normality assumption.

Linearity Test

The results of the linearity test showed a Deviation from Linearity significance value of 0.571 ($p > 0.05$), indicating that the relationship between early numeracy and numeracy AKM was linear. Therefore, the regression model satisfied the linearity assumption.

Multicollinearity Test

The multicollinearity test results showed a Tolerance value of 1.000 and a VIF value of 1.000, indicating that there was no multicollinearity among the variables in the regression model. This result shows that the predictor variables were not highly correlated with one another.

Heteroscedasticity Test

The Glejser test showed a significance value of 0.396 ($p > 0.05$), indicating that there was no heteroscedasticity problem. This means that the variance of the residuals was homogeneous, and the regression model could be considered to satisfy the homoscedasticity assumption.

Since all four assumptions were fulfilled, the regression model used in this study could be considered appropriate and valid for testing the effect of early numeracy on numeracy AKM results.

Simple Linear Regression Analysis

Simple linear regression analysis was conducted to determine the effect of early numeracy skills on numeracy AKM results. The strength of the relationship between early numeracy skills and numeracy AKM results, as well as the contribution of the early numeracy predictor variable to the dependent variable of numeracy AKM results, is presented in Table 1.

Table 1. Summary of the Simple Linear Regression Model between Early Numeracy and Numeracy AKM

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.491a	.241	.193	3.76190
a. Predictors: (Constant), Early Numeracy				

Source: Primary Data Analysis Results

Based on Table 1, the correlation coefficient (R) value of 0.491 indicates a positive and moderately strong linear relationship between early numeracy skills and numeracy AKM results. The coefficient of determination (R Square) value of 0.241 indicates that 24.1% of the variation in numeracy AKM results can be explained by students' early numeracy skills. The Adjusted R Square value of 0.193 indicates that approximately 19.3% of the variability can still be explained by the model after adjustment for sample size. Meanwhile, the Standard Error of the Estimate (SEE) value of 3.76190 indicates that the average deviation between the numeracy AKM results and the values predicted by the regression model was approximately 3.76 points.

To determine the overall significance of the regression model, an ANOVA test was conducted. The results are presented in Table 2.

Table 2. Result of the Simple Linear Regression Significance Test

ANOVA[a]						
Model		**Sum of Square**	**df**	**Mean Square**	**F**	**Sig.**
1	Regression	71.824	1	71.824	5.075	.039b
	Residual	226.430	16	14.152		
	Total	298.255	17			
a. Dependent Variable: Numeracy AKM						
b. Predictors: (Constant), Early Numeracy						

The ANOVA test results showed that the calculated F value was 5.075 with a significance value of 0.039, which was smaller than 0.05. This indicates that the regression model used in this study was statistically significant. In other words, early numeracy skills as a whole had a significant effect on numeracy AKM results.

To determine the change in numeracy AKM results resulting from an increase in early numeracy skills, assuming other variables remained constant, a coefficient analysis was conducted. The results of the simple linear regression coefficient analysis are presented in Table 3.

Table 3. Simple Linear Regression Coefficients

Coefficients[a]					
	Unstandardized Coefficients		Standardized Coefficients		
Model	B	Std. Error	Beta	T	Sig.
1 (Constant)	8.036	3.124		2.573	.020
Early Numeracy	.154	.068	.491	2.253	.039
a. Dependent Variable: Numeracy AKM					

Source: Primary Data Analysis Results

Based on Table 3, the early numeracy variable had a regression coefficient of 0.154 with a significance value of 0.039. This means that every 1-point increase in students' early numeracy skills was followed by an increase of approximately 0.154 points in students' numeracy AKM results, assuming other variables remained constant. Because the significance value of 0.039 was smaller than 0.05, the effect on numeracy AKM results was statistically significant ($p < 0.05$).

Qualitative Result

The results of the in-depth interviews conducted by the researcher (P) with the research subject (S), a second-grade student of SDN 218/IV Jambi City, revealed five main themes representing the student's understanding and strategies in solving numeracy tasks within the conceptual framework of the Early Grade Mathematics Assessment.

Early Introduction to Numbers in the Home Environment

The student reported having recognized numbers at the age of 3–4 years before entering elementary school through informal activities at home with their mother, father, and older sibling. The older sibling was the person who most frequently acted as a guide in teaching numbers. The following is an excerpt from the interview.

P : "...At what age did you start recognizing numbers?"
S : "At around 3 to 4 years old."
P : "...Who usually taught you numbers at home?"
S : "Sometimes Mom, sometimes Dad, sometimes my older sister."
P : "...Who taught you most often?"
S : "My older sister."

These findings indicate that early numeracy experiences are not formed only at school but are also strongly influenced by the role of the family. Furthermore, the respondent stated that they began learning letters and numbers using pencils and books to practice writing letters and numbers.

Misunderstanding of Place Value

To explore the student's basic understanding of number concepts, the student was first asked to mention the names of numbers written by the researcher. The respondent was given the two-digit numbers 12 and 45, followed by the three-digit number 108. The results showed that the respondent was able to correctly name the numbers.

The respondent was then asked to identify the ones, tens, and hundreds digits in the numbers 12, 45, and 108. From this activity, it was found that the student still made errors and experienced confusion in identifying the ones, tens, and hundreds digits. The following excerpt presents the interview between the researcher and the student.

P : *"What number is this?"* (writes 12 on a piece of paper)
S : *"Twelve."*
P : *"... In the number twelve, which digit is the ones digit?"*
S : *"This is the ones digit."* (while pointing with a finger to the digit 1) *"The digit one."*
P : *"... Which digit is the tens digit?"*
S : *"This is the tens digit."* (pointing to the digit 2)
P : *"What number is this?"* (writes the number 45)
S : *"Forty-five."*
P : *"For this number"* (pointing to 45), *"which digit is the ones digit?"*
S : *"The ones digit is four." (pointing to the digit 4 in 45)*
P : *"... Then what about five, is it the ones digit or the tens digit?"*
S : *"The tens digit."*
P : *"... What number is this, dear?"* (writes the number 108)
S : *"One hundred eight."*
P : *"Which digit is the tens digit?"*
S : *"The zeeo."*
P : *"Why is it called the tens digit?"*
S : *"Because it is in the middle."*

To further explore the meaning of numbers, the researcher then asked the student to take twelve bottle caps and fifteen bottle caps. In this activity, the student was able to select the correct number of bottle caps. Next, the researcher asked the student to write the number fifteen on a piece of paper. The result showed that the student was also able to write the number fifteen correctly using the appropriate symbol, namely 15.

The researcher then explored the student's ability to compare the magnitude of numbers. The researcher presented the numbers 42 and 24 and asked the student to state the names of the numbers. The results showed that the student was able to identify 42 as forty-two and 24 as twenty-four. After that, the researcher asked the student to indicate which of the two numbers was greater. The student correctly identified 42 as being greater than 24. When asked for the reason, the student stated that the digit 4 in 42 was greater than the digit 2 in 24.

Based on the interview results, the student's understanding of place value had not yet been fully developed conceptually. Although the student was able to correctly read two-digit and three-digit numbers, represent numerical quantities correctly using concrete objects, and compare the magnitude of numbers accurately, the conceptual understanding of place value remained incomplete.

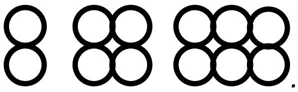
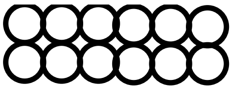
Ability to Recognize and Extend Patterns

The researcher explored the student's ability to recognize and extend repeating patterns and growing patterns (patterns that increase and decrease). Initially, the researcher asked the student to provide examples of patterns that could be found in the surrounding environment. From this question, it was found that the student was still confused about identifying real-life examples of patterns.

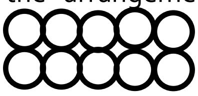
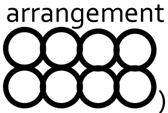
Next, the researcher invited the student to explore patterns using colored buttons. In the task involving repeating patterns, the researcher provided a sequence of buttons consisting of three different colors and then asked the student to identify the color of the next button in the sequence. In this activity, the student was able to correctly continue the repeating color pattern, as shown in the following interview excerpt.

P : *"... If I have a pattern like this* *, ... what is the next color?"*
S : *Green, brown, white, green, brown."* (while naming the colors and arranging the buttons into the pattern shown )

However, the student still experienced difficulties when given questions involving increasing and decreasing patterns, as shown in the following interview excerpt.

P : *"... I have this pattern*  *. How many bottle caps are there?"*
S : *"Two, ... this is four..., ... this is six."* (while pointing to the arrangement of bottle caps)
P : *"... What would the next arrangement look like?"*
S : *"... Like this*  *"* (arranging the bottle caps)

When the student was asked to complete a task involving a decreasing pattern, the student also experienced difficulties and required guidance to arrive at the answer. The following excerpt illustrates the interview.

P : *"What if the pattern is reversed, starting from here?"* (pointing to the arrangement of bottle caps )
S : *"This is ten."*
P : *"Then?"* (pointing to the arrangement of bottle caps )
S : *"Six. Oh, eight."*

Based on the interview results, the student's understanding of patterns was still limited to repeating patterns. However, the student continued to experience difficulties when confronted with patterns that required simple arithmetic operations, such as increasing and decreasing quantities.

Concrete Strategies as Thinking Tools

The researcher explored the student's thinking process in solving simple addition and subtraction operations. The researcher provided the student with paper and a pencil as counting aids, in addition to buttons and bottle caps. Based on the interviews and observations conducted, it was found that the student was more comfortable solving arithmetic problems using fingers or concrete objects, as illustrated in the following interview excerpts.

P : *"... I have six marbles, but my teacher asked me to bring ten marbles. So, ... how many more marbles do I need?"*
S : *"Four."*
P : *"... How did you get four?"*
S : *"Because you were asked to bring ten."* (showing 10 fingers) *"Then you have six."* (showing 6 fingers) *"This is six, plus four makes ten."*
P : *"... If I have ten pencils, and then three pencils are taken away, how many pencils are left?"*
S : *"... Seven...."*
P : *"How did you calculate it?"*
S : *"Umm... just think about it, umm... you have ten."* (showing 10 fingers) *"Then, you subtract three from ten, and the remainder is seven..."* (showing 7 fingers).

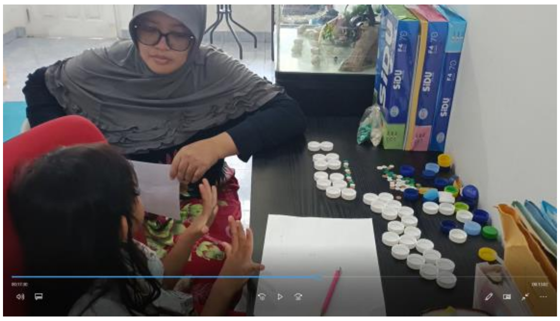
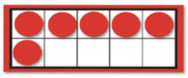
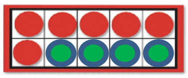


Figure 2. Student Using Fingers for Counting

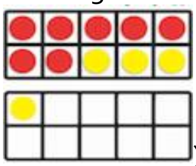
To further explore the student's thinking process in solving addition and subtraction operations using visual representations, the researcher provided activities involving a ten-frame and a number line. The student was not yet familiar with these tools and therefore still required guidance from the researcher when using them. The following excerpts illustrate the interview.

P : *"I have a ten-frame with counters arranged like this*  *, How many counters are needed to make ten?"*

S : *"Four."* (taking counters and placing them in the ten-frame until it looked like this )

P : *"... There are six counters. If I remove one counter, how many counters are left?"* (while covering one counter on the ten-frame)

S : *"Umm... Five."*

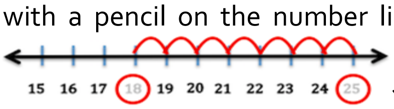
P : *"I have seven bottle caps."* (pointing to the red circles) *"Then I add four bottle caps."* (pointing to the yellow circles) *"So, there are seven red bottle caps and four yellow bottle caps are added. How many bottle caps are there altogether?"* (while showing two ten-frames )

S : *"It becomes... ten."*

P : *"Let's count again."*

S : *"Eleven."*

P : *"I have a number line... If I start from twenty-five here... Count backward by seven. What number do I get?"* (pointing to the number line)

S : *"Nineteen."* (drawing jump arcs with a pencil on the number line 

)

P : *"Nineteen? Let's count together. One..."*

S : *"Two... three... four... five... six... seven."*

P : *"So, what number do you get?"*

S : *"Eighteen."*

Based on the interview and observation results, it was found that the use of visual manipulative materials had not yet been fully mastered. The student still required guidance in using visual representation tools.

Difficulties with Vertical Operations

The researcher conducted a further interview with the student to investigate the student's ability to perform more abstract mathematical representations. The researcher presented a word problem and asked the student to provide an answer. The following excerpt illustrates the interview.

P : *"I have twelve marbles, and you have seven marbles. If all the marbles are combined, how many marbles are there altogether?"*

S : (Calculating mentally for a few moments, then continuing the calculation using fingers) *"Nineteen."*

P : *"How would you write the notation? Write the, umm... the addition sentence?"*

S : (Silent)

P : *"... How would you write twelve plus seven equals nineteen?"*

S : (Writes $12 + 7 = 19$ on the paper while saying) *"twelve plus seven equals nineteen' aloud."*

At this stage, the student still demonstrated the ability to solve simple addition operations using fingers as a concrete aid. However, the student still experienced difficulties in representing a word problem in symbolic mathematical form. The student still required assistance in connecting everyday language with mathematical symbols.

The same finding was obtained when the researcher presented a word problem related to a simple subtraction operation.

P : *"If there are twenty students in a classroom, but only sixteen come to school, how many students are absent?"*
S : (Silent)
P : *"There are twenty students, but only sixteen are present. So, how many students are absent?"*
S : *"Umm... Four."*
P : *"Then how would you write it like this?"* (pointing to the previous addition notation example) *"... The total number of students is twenty, sixteen are present, and four are absent. Does this involve addition or subtraction?"*
S : *"Subtraction."*
P : *"How would you write it?"*
S : *"Twenty minus, umm..."* (stops)
P : *"Minus how many?"*
S : *"Four..."*
P : *"Uh-huh"*
S : *"Equals..."* (while writing)
P : *"Uh-huh"*
S : *"Twenty minus four equals sixteen."* (while writing 20 – 4 = 16)

During the interview, the student further explained to the researcher that to solve the operation 12 + 7, the student would usually draw twelve circles to assist with counting. The student was also familiar with performing calculations using the vertical algorithm. However, when the researcher asked which method was easier solving the problem on paper (while pointing to the student's work using the vertical algorithm) or using fingers (while demonstrating finger counting) the student stated that using fingers was easier.

P : *"... Which is easier, calculating like this?"* (pointing to the written vertical addition operation on paper) *"Or like this?"* (demonstrating finger counting)
S : *"Easieeer... umm... fingers."*
P : *"Why fingers?"*
S : *"He... he..."* (smiling)

These findings indicate that the transition to symbolic operations had not yet been fully developed. In addition to the observations, the interview findings were also supported by the student's learning artifacts related to solving arithmetic operations using the vertical algorithm. The student's work showed that the student still experienced confusion when solving arithmetic operations using the vertical algorithm, particularly subtraction operations. These findings confirm that the student continued to rely on concrete strategies as counting aids.

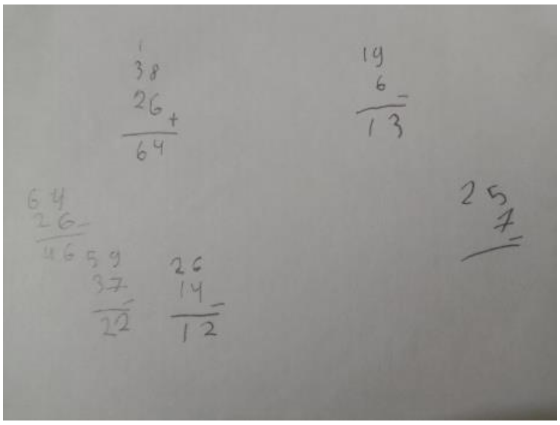


Figure 3. Student Work on the Vertical Algorithm

Overall, the findings of this study confirm that early numeracy skills can serve as predictors of numeracy proficiency measured through formal assessments such as the Minimum Competency Assessment. The quantitative findings revealed a positive and statistically significant relationship between early numeracy skills and numeracy AKM results. These findings were further supported by the qualitative findings obtained through interviews and observations, which showed that the thinking processes and numeracy concept understanding of second-grade students were still at the concrete operational stage, relying on finger-counting strategies and manipulative materials, while experiencing difficulties in understanding place value and symbolic operations. The qualitative findings in this study were integrated to explain and deepen the quantitative results, particularly in revealing the students' thinking processes, problem-solving strategies, and limitations in conceptual understanding that underlie their numeracy AKM performance.

Discussion

The quantitative analysis results showed that early numeracy skills had a significant effect on numeracy AKM achievement, although the contribution was within the moderate category. These findings indicate that early numeracy serves as an important foundation for the development of more advanced numeracy skills; however, it does not fully explain the variation in students' numeracy AKM achievement. Therefore, the qualitative findings in this study were integrated to explain and deepen the quantitative results by revealing the thinking processes, problem-solving strategies, and forms of conceptual difficulties experienced by students in the early grades.

The findings from the simple linear regression analysis, which showed that early numeracy skills had a significant overall effect on numeracy AKM results with a contribution of 24.1% (p = 0.039), are consistent with previous studies emphasizing the importance of early numeracy for academic success (Duncan et al., 2007; Duncan & Magnuson, 2011; Jordan et al., 2009, 2010; Locuniak & Jordan, 2008). The findings from the simple linear regression analysis, which showed that early numeracy skills had a significant overall effect on numeracy AKM results with a contribution of 24.1% (p = 0.039), are consistent with previous studies emphasizing the importance of early numeracy for academic success.

Although the statistical power of this study was not entirely strong due to the limited sample size, the consistent direction of the relationship and the achieved statistical significance still provide meaningful preliminary evidence from a practical perspective. These findings strengthen the assumption that early numeracy skills make a tangible contribution to performance on national assessments such as AKM. Furthermore, these findings highlight the importance of strengthening numeracy skills in the early grades of elementary school.

These findings further confirm that early numeracy serves as an important foundation for the development of more advanced numeracy skills. The findings are consistent with meta-analytic evidence indicating that early numeracy skills contribute significantly to the achievement of more complex mathematical competencies in later years. The predictive nature of early numeracy skills is cumulative in relation to children's numeracy development (Liu et al., 2025; Lopez-Pedersen et al., 2023).

However, the relatively moderate magnitude of the contribution also indicates that students' numeracy achievement cannot be fully explained solely by the aspects of early numeracy measured through formal assessments. This finding is consistent with Chang (2023), whose further analysis of TIMSS data showed that the influence of early numeracy on mathematics achievement does not operate independently, but is affected by other factors such as early literacy skills, home resources, and the interaction between early numeracy skills and other contextual variables in shaping subsequent numeracy achievement. In other words, early numeracy is an important predictor, but the strength of its influence may vary depending on other skills and the learning environment of the student.

The in-depth interview results enriched the interpretation of these quantitative findings. The respondent indicated that the family environment played an important role in the early introduction to numbers. The student began learning numbers at the age of 3–4 years before entering formal schooling through guidance from their mother, father, and older sibling, using simple tools such as pencils and books. These findings reinforce the view that early numeracy experiences are contextual in nature and are strongly influenced by social interactions and support from the informal learning environment (Sitabkhan et al., 2018). The findings also support previous studies showing an association between numeracy skills and home-based counting activities (Hwang, 2020), as well as the influence of parental support on students' learning outcomes (Khasanah & Abduh, 2023).

Informal experiences derived from children's everyday interactions at home, such as counting objects, comparing quantities, and recognizing simple patterns, also contribute to the development of early numeracy skills (Ramani et al., 2015). This finding highlights the need for numeracy assessments that are aligned with and more sensitive to the informal mathematical knowledge of students in the early grades (Sitabkhan et al., 2018). Furthermore, diverse, contextual, and child-centered approaches to early numeracy research are essential for the development of assessment and instructional interventions that are appropriate to children's developmental characteristics (Holmes & Dowker, 2013; Outhwaite et al., 2024; Way, 2023). Consequently, formal assessments such as AKM continue to face methodological challenges. Although AKM is designed to be context-based, it still requires certain levels of symbolic understanding and abstraction that may not be fully aligned with the concrete operational thinking characteristics of students in the early grades (Rohim et al., 2021).

The interviews also revealed a gap between number recognition and conceptual understanding. For example, the respondent was able to identify "12" as twelve and "45" as forty-five but experienced difficulty in accurately explaining the ones and tens places. This finding indicates that although the student could verbally identify numbers, a deeper understanding of concepts such as place value had not yet been fully developed. This result is consistent with a study reporting that 68% of students made conceptual errors when solving place value problems (Harianti et al., 2022). The finding also supports previous research on the influence of number naming systems on place value understanding (Browning & Beauford, 2012). Place value understanding also plays an important role in number writing, particularly for more complex numbers (Herzog & Fritz, 2022). Therefore, it is important for teachers to integrate contextual and manipulative activities to support students in the early grades in developing place value understanding (Durmaz & Miçooğullari, 2021; Fraivillig, 2018; Jensen et al., 2024).

In comparing numerical

magnitudes, the student correctly stated that 42 was greater than 24 because the digit 4 in 42 was larger than the digit 2 in 24. This response suggests that the student appeared to rely on a learned rule by comparing the larger leftmost digit without referring to the quantitative meaning or place value of 4 as 40 and 2 as 20 (Nuerk et al., 2010). This finding is consistent with studies showing that students' ability to compare numbers is often based on procedural knowledge rather than a conceptual understanding of place value (Herzog & Fritz, 2022).

During the interviews and pattern exploration activities, the student demonstrated the ability to recognize repeating patterns. However, the student still experienced difficulties and required assistance in understanding simple increasing and decreasing patterns. This result is consistent with findings indicating that repeating-pattern tasks are generally easier than growing-pattern tasks (Borriello et al., 2023). Meanwhile, the ability to understand shape patterns and number patterns is considered an important indicator of numeracy proficiency, particularly in relation to logical reasoning and representational skills (Rivera, 2018). Pattern understanding is also recognized as an early indicator of algebraic reasoning and mathematical thinking (Burgoyne et al., 2019; Kidd et al., 2014). Mastery of repeating and growing patterns in the early grades contributes to students' overall numeracy development (Mix et al., 2022, 2023). Therefore, it is important for educators to integrate learning activities that connect repeating patterns and growing patterns with classroom instruction.

Furthermore, the interview and observation results showed that, when performing basic mathematical operations, the student tended to rely on concrete strategies such as finger counting and the use of manipulative objects, including bottle caps and buttons. The student reported feeling more comfortable and efficient when counting with fingers than when using symbolic algorithms and vertical arithmetic procedures. This strategy indicates that the student was still at the enactive representation stage, in which learning occurs through physical actions and direct experiences with real-world objects (Bruner, 1964). This interpretation is supported by research demonstrating the positive effects of manipulative materials on the mathematics achievement of second-grade students (Liggett, 2017). The finding is also consistent with the view that students in the concrete operational stage continue to require tangible supports in order to develop abstract mathematical understanding (Piaget, 1964).

During the activities exploring iconic representation skills using ten-frames and number lines, the student was able to solve arithmetic operations only under the guidance of the researcher. Thus, it can be argued that the student's transition from enactive to symbolic representation had not yet been fully developed. Therefore, the use of manipulative materials to facilitate the transition from enactive to symbolic representation in second grade is highly necessary (Żądło-Treder, 2021)

When presented with vertical arithmetic operations, the student was able to solve addition problems. However, the student still experienced confusion when solving subtraction problems involving the concept of regrouping (borrowing). This finding is consistent with studies indicating that many students in the early grades experience difficulties with vertical arithmetic procedures when concrete strategies have not been sufficiently developed (Napfiah & Zahro, 2022). This suggests that procedural mastery without adequate conceptual understanding tends to be fragile, particularly when it is not supported by sufficient concrete experiences to strengthen understanding (Schneider & Stern, 2010).

Overall, these quantitative and qualitative findings confirm that, in addition to functioning as an assessment instrument for analyzing students' early numeracy skills, EGMA can also serve as a conceptual framework for explaining the structure and characteristics of early numeracy development (RTI International, 2009). EGMA enables researchers and educators to capture the thinking processes of students in the early grades of elementary school. Therefore, the findings of this study not only measure numeracy achievement but also provide important insights for the design of numeracy interventions, educational policies, and methodological approaches that are aligned with the developmental characteristics of children in the early grades of elementary school.

The integration of these two sets of findings demonstrates that limitations in numeracy AKM achievement are closely related to the predominance of enactive and, to some extent, iconic representations in solving numeracy tasks, while the ability to use symbolic representations has not yet developed optimally. According to Bruner's theory of representation, mathematical understanding develops through the interconnected and sequential stages of enactive, iconic, and symbolic representation (Bruner, 1964). The qualitative findings, which revealed students' difficulties in understanding place value, performing vertical arithmetic procedures, and identifying increasing and decreasing patterns, provide a conceptual explanation for the statistically moderate contribution of early numeracy. Therefore, the integration of the quantitative and qualitative findings confirms that strengthening early numeracy should focus on systematically facilitating the transition from concrete to symbolic representation in order to promote sustained improvement in students' numeracy achievement.

Implication

This study provides several implications for educational stakeholders. For teachers, the findings underscore the importance of strengthening students' early numeracy skills through the use of concrete objects, physical counting strategies, manipulative materials, and contextualized classroom activities. For parents, the study highlights the critical role of the family in introducing numeracy from an early age, as informal learning experiences at home contribute significantly to the development of children's numeracy skills. For policymakers, the findings suggest the need to review and refine numeracy assessment formats for students in the early grades to ensure greater alignment with children's developmental stages of thinking. For future researchers, this study offers opportunities to extend the investigation by involving larger sample sizes, diverse school contexts, additional variables that may influence students' numeracy skills, and comparative approaches to further validate the predictive power of early numeracy skills on numeracy assessment outcomes.

Limitation

This study was conducted in an educational institution selected by the researcher; therefore, the generalizability of the findings is limited to contexts that are similar to those of the participants involved in this study. In addition, the sample size was relatively small, consisting of only 18 students (n = 18), which limits the extent to which the findings can be generalized to broader populations. Consequently, the results should be interpreted primarily as a contextualized preliminary picture rather than as broadly generalizable evidence. Furthermore, this study focused exclusively on early numeracy components as defined by the Early Grade Mathematics Assessment (EGMA), including number recognition, number comparison, number patterns, Level 1 addition, Level 2 addition, Level 1 subtraction, Level 2 subtraction, and word problems. Therefore, other potentially influential factors, such as motivation, mathematics anxiety, learning styles, socioeconomic background, and related variables, were not taken into account, although these factors may also have affected the measurement outcomes.

CONCLUSION

Based on the findings of this study, it can be concluded that early numeracy skills have a significant effect on numeracy achievement in the Minimum Competency Assessment (AKM) among second-grade students at SDN 218/Jambi City, contributing 24.1% of the variance (p = 0.039). The stronger the students' early numeracy skills, the greater their likelihood of achieving the minimum numeracy competency. The interview findings further revealed that family support, the use of concrete objects, and finger-counting strategies play important roles in the development of children's early numeracy skills. Therefore, strengthening numeracy from an early age, both at home and at school, is essential for supporting students' success in learning mathematics at subsequent levels of education.

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