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Diagnostic assessment of students' numeracy ability in phase a using the finger math method: Analysis of patterns of accuracy and speed of answer

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Abstract: This study aims to conduct a diagnostic assessment of Phase A students' numeracy skills by analyzing answer accuracy and calculation speed using the finger-math method. The study is grounded in the low numeracy performance of students in private Islamic elementary schools and the continued dominance of conventional learning approaches that give limited attention to students' numeracy processes. A quantitative approach with a quasi-experimental non-equivalent control group design was employed. The sample consisted of 100 second-grade students in Manado, divided into an experimental group that received finger math instruction and a control group that received conventional instruction. Data were collected using a numeracy test and analyzed using one-way MANOVA. The findings show that the finger math method has a significant simultaneous effect on calculation accuracy and speed, as indicated by Wilks' Lambda = 0.045, $p < 0.001$. The subsequent univariate ANOVA tests also show significant effects on calculation accuracy ($F = 830.277$, $p < 0.001$) and calculation speed ($F = 1.094.872$, $p < 0.001$). Descriptively, students in the experimental group demonstrate higher accuracy and faster completion times than those in the control group. These findings indicate that finger math is effective not only in improving calculation accuracy but also in enhancing processing efficiency in early numeracy learning. The study further highlights the importance of integrating accuracy and speed as complementary indicators in diagnostic assessment to provide a more comprehensive understanding of Phase A students' numeracy ability profiles.
Keywords: diagnostic assessment, finger math, numeracy, accuracy, speed

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Introduction

Numeracy skills are a fundamental part of elementary school mathematics learning. These skills encompass two important aspects: accuracy in obtaining answers and speed in solving problems. Both aspects are important indicators of students' numeracy literacy. Numeracy literacy plays a role in helping students understand number concepts, basic operations, and their application in everyday life (Baird, 2017; Geary, 2011; Panadero, 2018). In the 21st century, numeracy skills are not only an indicator of learning success but also an important asset in a digital, data-based daily life (Tout, 2021). Students are required not only to be able to calculate correctly, but also to be efficient and flexible in various numerical problem-solving situations (Powell, 2022).

Diagnostic assessment plays a strategic role in identifying students' learning readiness, strengths, and difficulties, particularly in numeracy learning at the early stages of primary education (Heritage, 2021; Panadero, 2018). Within the Merdeka Curriculum framework, numeracy is positioned as a core competency, emphasizing the importance of understanding mathematical concepts and applying them in real-life contexts (Jonas, 2018; Wijaya, 2015). However, effective diagnostic assessment should go beyond evaluating final results by capturing students' thinking processes, including their accuracy and speed in performing calculations (Clarke, 2001; Roy, 2025).

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Despite its importance, current assessment practices in elementary education, particularly in Islamic elementary schools tend to focus primarily on answer accuracy, while calculation speed is rarely used as a diagnostic indicator. Moreover, previous studies have rarely integrated the simultaneous analysis of accuracy and speed within a diagnostic assessment framework. This creates a significant gap in comprehensively understanding students' numeracy profiles, especially in identifying whether difficulties stem from conceptual misunderstanding, procedural fluency, or limited cognitive processing speed. Furthermore, empirical data describing students' numeracy profiles based on these two aspects, particularly in Phase A students in North Sulawesi, remain very limited.

In line with this, various international studies indicate that students' numeracy skills in many developing educational contexts, including Indonesia, are still categorized as relatively low, particularly in terms of efficiency and accuracy in solving mathematical problems. Contemporary educational research highlights that many students experience difficulties in applying mathematical knowledge flexibly and effectively in authentic situations, a challenge that remains a major challenge in 21st-century education (Voskoglou, 2020). Meanwhile, the results of the 2019 Trends in International Mathematics and Science Study (TIMSS) showed that Indonesian students had difficulty solving basic arithmetic problems accurately and quickly (Liu, 2024). These findings indicate a gap between learning outcomes and the demands of 21st-century numeracy competencies, while emphasizing the importance of a more in-depth diagnostic assessment approach.

One factor contributing to students' low numeracy skills is the dominance of conventional, abstract, and memorization-oriented learning approaches. From an epistemological perspective, mathematics learning for elementary school-aged children should be built through concrete experiences and representations close to the child's world (Lafay, 2023; Ponte, 2023). Learning that lacks kinesthetic and manipulative activities has the potential to hinder the development of meaningful conceptual understanding (Carbonneau, 2013; Vallejo-Vargas, 2024). Several studies have shown that kinesthetic-based learning approaches and the use of concrete aids, such as fingers for counting, can increase student engagement and the effectiveness of mathematics learning (Fischer, 2011)

In this context, finger math emerges as a relevant kinesthetic-based approach that utilizes finger representations as a visual and kinesthetic medium. This method has been widely implemented in several East Asian countries, including South Korea, Japan, and China, and has proven effective in improving counting accuracy and speed from early childhood through elementary school. Previous research also shows that finger representation-based counting skills correlate significantly with children's early arithmetic achievement (Neveu, 2023; Poletti, 2023). In Indonesia, several studies have reported that finger math can improve students' understanding of number concepts and basic operations, reduce math anxiety, and encourage active student engagement in learning (Baroody, 2006; Friedman et al., 2018; Lestari, 2020; Moeller et al., 2012).

However, the implementation of finger math in Indonesian elementary schools, particularly in Islamic elementary schools, remains limited and has not been systematically integrated with diagnostic assessments capable of simultaneously mapping calculation accuracy and speed. This situation is increasingly evident in eastern Indonesia, such as North Sulawesi, where mathematics learning is still dominated by repetitive practice problems and formula memorization, with little use of kinesthetic or manipulative calculation strategies.

This study offers novelty by integrating diagnostic assessment with the simultaneous analysis of accuracy and speed, a rarely examined combination. Furthermore, there is still a lack of empirical data describing numeracy ability profiles of Phase A students in Islamic Elementary Schools in North Sulawesi using this approach. Therefore, this study aims to identify students' numeracy ability profiles based on accuracy and speed through diagnostic assessment, and to examine the effect of finger math, a kinesthetic-based intervention, on improving students' numeracy performance. The findings are expected to contribute to the development of more comprehensive diagnostic assessment practices and to provide practical implications for improving mathematics learning in primary education.

Methods

This study employed a quantitative, quasi-experimental design, specifically a non-equivalent control group design. The previous designation as a factorial design is not appropriate, as this study involved only one independent variable with two treatment groups. The quasi-experimental design was chosen due to practical limitations in applying full randomization within the private Islamic elementary schools setting, especially in Phase A classes, where existing classroom structures needed to be maintained for instructional and administrative reasons. According to quasi-experimental research principles, intact groups are frequently used in educational contexts when random assignment is difficult or impossible to implement (Campbell, 1963; Gopalan, 2020; Karim, 2025). The study involved one independent variable, namely the learning method, with two categories: finger math (A1) and conventional learning (A2). In addition, there were two dependent variables, namely accuracy (Y1) and calculation speed (Y2), which were analyzed simultaneously. The research design can be presented as follows.

Table 1. Research Design

Group	Treatment	Posttest
Experimental	Finger Math (A1)	Y1, Y2
Control	Conventional (A2)	Y1, Y2

Description:
Y = (Y1,Y2) : mean vector of dependent variables
Y1 : Accuracy
Y2 : Speed

The population in this study was all second-grade students of Islamic Elementary Schools (MI) in Manado in the even semester of the 2024/2025 academic year. The sampling technique used was purposive sampling, which involves selecting samples based on specific criteria relevant to the research objectives (Haenilah, 2023). The sample consisted of an experimental group, namely second-grade students from private Islamic elementary schools in Paal Dua sub-district, who received instruction using the finger math method. The control group, namely second-grade students of private Islamic elementary schools located in Tuminting sub-district, received learning using conventional methods. Each group consisted of 50 students, for a total of 100 students. However, purposive sampling from two schools has the potential to introduce selection bias and is therefore acknowledged as a limitation of this study.

Data were collected using a numeracy test designed to measure students' accuracy and speed in basic arithmetic operations. The instrument consisted of a set of test items covering indicators such as understanding number concepts, performing basic arithmetic operations, and procedural fluency. Accuracy (Y1) was measured as the number of correct answers obtained by students and converted to a standardized score. Calculation speed (Y2) was measured based on the time required for students to complete all test items, expressed in minutes and seconds. The shorter the completion time required, the higher the student's calculation speed. This measurement reflects cognitive efficiency, particularly in the automation of arithmetic processes and numerical information processing (Geary, 2011; Kovarsky Rotta, 2026; Sweller, 2011). To ensure the instrument's quality, validation procedures were conducted using content validity by expert judgment and supported by empirical testing. Reliability testing was also conducted to ensure consistency of measurement results.

The research was conducted in several stages, including instrument preparation, validation, treatment implementation, and data collection. The experimental group received instruction using the finger math method, while the control group received conventional learning. The treatment was implemented during the mathematics learning process in regular classroom settings. However, this study did not employ a pretest; therefore, initial equivalence between groups was not statistically tested, and this is acknowledged as a limitation.

The research data were analyzed using Multivariate Analysis of Variance (MANOVA) because there were two dependent variables: speed and calculation accuracy. The analysis used was One-Way MANOVA to simultaneously test the effect of learning methods on both dependent variables and detect the main effect of treatment (Finch, 2022; Garcia-Perez, 2021). The analysis was carried out with the following steps: MANOVA prerequisite tests: Multivariate normality (Mardia's Test), Homogeneity of covariance (Box's M Test), Correlation between dependent variables. Significance test using Wilks' Lambda. If MANOVA is significant, it is continued with univariate ANOVA as a further analysis (follow-up tests). In addition, effect size was reported to provide a more comprehensive interpretation of the magnitude of the treatment effect.

Accuracy (Y1) refers to the level of correctness in students' answers, measured by the number of correct responses and converted into a standardized score. Calculation Speed (Y2) refers to the time required to complete all test items, measured in minutes and seconds. Faster completion time indicates higher efficiency in numerical processing. Calculation speed reflects the fluency of numerical information processing and the level of automation in arithmetic operations, which are closely related to working memory efficiency and cognitive load (Geary, 2011; Kovarsky Rotta, 2026).

Results and Discussion

Results

Descriptive Analysis

Descriptive statistics were used to summarize students' numeracy performance based on two indicators: calculation accuracy (Y_1) and calculation speed (Y_2). The mean and standard deviation of each group are presented in Table 2.

Table 2. Mean and Standard Deviation of Numeracy Ability

Calculation Accuracy (Y1)	Control (X1=0)	67.06	3.74	50
	Experimental (X1=1)	86.86	3.09	50
	Total	76.96	10.52	100
Calculation Speed (Y2)	Control (X1=0)	112.10	4.42	50
	Experimental (X1=1)	85.36	3.61	50
	Total	98.73	14.02	100

The experimental group showed higher mean accuracy and lower mean completion time (in seconds) compared to the control group. These patterns indicate a consistent tendency toward better performance in the experimental group across both indicators, suggesting more efficient and stable numeracy processing. The distribution of students across accuracy and speed categories is presented in Tables 3 and 4

Table 3. Percentage of Calculation Accuracy

Accuracy Category	**Finger Math**		**Conventional**	
	Number of Students	**Percentage**	**Number of Students**	**Percentage**
High (≥ 85)	30	60%	18	36%
Medium (70–84)	15	30%	20	40%
Low (< 70)	5	10%	12	24%
Total	50	100%	50	100%

Table 3 shows that a higher proportion of students in the experimental group were in the high-accuracy category than in the control group. This distribution reflects a shift toward higher mastery levels in the experimental group, with fewer students remaining in lower-performing categories.

Table 4. Percentage of Calculation Speed

Speed Category	**Finger Math**		**Conventional**	
	Number of Students	**Percentage**	**Number of Students**	**Percentage**
Fast (≤ 90 seconds)	28	56%	15	30%
Medium (91–110 seconds)	17	34%	20	40%
Low (> 110 seconds)	5	10%	15	30%
Total	50	100%	50	100%

Table 4 presents the distribution of students based on calculation speed categories. The experimental group had a higher proportion of students in the fast category than the control group. The pattern suggests that more students in the experimental group achieved higher levels of processing efficiency, indicating improved fluency in performing basic arithmetic operations.

Descriptively, diagnostic assessments based on accuracy and calculation speed can reveal more comprehensively differences in students' calculation abilities between groups. The integration of these two indicators contributes to the research's novelty, as most previous studies have only partially assessed calculation abilities. These descriptive results then serve as an initial empirical basis for simultaneously testing the effectiveness of the finger math method through inferential analysis.

Inferential Analysis

Before conducting the MANOVA, assumption tests were performed to ensure the data met the required statistical assumptions. Table 5 presents the results of the Box's M test for homogeneity of covariance matrices.

Table 5. Result of Box's M Test (Homogeneity of Covariance Matrix)

Box's M	F	df1	df2	Sig.
3.717	1.212	3	17287	0.304

Based on Table 5, the assumption of homogeneity of covariance matrices was met ($p > 0.05$). Table 6 shows the results of Levene's test for homogeneity of variance.

Table 6. Levene's Test (Homogeneity of Variance)

Variable	Levene Statistic	Df1	Df2	Sign.
Calculation Accuracy	1.473	1	98	0.228
Calculation Speed	1.381	1	98	0.245

Table 6 shows that both variables met the assumption of homogeneity of variance ($p > 0.05$). Table 7 presents the results of the multivariate analysis using MANOVA.

Table 7. Multivariate Test

Effect	Wilks' Lambda	F	Hypothesis df	Error df	Sig.
Method	0.045	1033.545	2	97	0.000

Based on Table 7, the results indicated a statistically significant multivariate effect of the learning method on the combined dependent variables, with Wilks' Lambda = 0.045 and $F(2, 97) = 1033.545$, $p < .001$. Effect size estimation (partial $\eta^2 = 0.89$) indicated a very large effect, suggesting that the learning method accounted for a substantial proportion of variance in the combined dependent variables. These findings suggest that the learning method is not only statistically significant but also practically meaningful in enhancing students' numeracy performance.

Table 8. Univariate Test Results (ANOVA)

Variable	F	Sig.	Power
Calculation Accuracy	830.277	0.000	1.000
Calculation Speed	1.094.872	0.000	1.000

Table 8 presents the results of the univariate ANOVA for each dependent variable. Based on Table 8, both variables showed statistically significant differences between groups ($p < 0.001$). Effect size estimates (partial η^2) indicated large effects for both accuracy and calculation speed, suggesting that the learning method had a substantial impact on students' numeracy performance. The high F values may reflect substantial between-group differences relative to within-group variance.

Discussion

The findings of this study indicate that students in the experimental group demonstrated a higher numeracy profile than those in the control group, as reflected in both calculation accuracy and speed. These results suggest that the finger math method not only improves the correctness of students' responses but also enhances the efficiency of their calculation processes.

The results of the one-way MANOVA further confirmed that the learning method had a statistically significant multivariate effect on students' numeracy performance. From a cognitive perspective, this effect can be explained by the role of sensorimotor engagement in learning. The use of fingers as a representational tool enables students to connect abstract numerical symbols with concrete physical experiences, thereby reducing cognitive load and supporting more efficient information processing. This explanation is consistent with cognitive load theory, which emphasizes that meaningful learning occurs when cognitive demands are effectively managed (Sweller, 2011).

This finding is consistent with prior studies by Neveu et al. (2012), which highlight that finger-based representations play a crucial role in strengthening number sense and supporting early arithmetic development. Finger representations help bridge the gap between concrete and abstract thinking, particularly in early-grade learners (Neveu, 2023). Similarly, Kim and Park (2018) found that hand-gesture-based learning enhances the integration of visual and kinesthetic memory, thereby improving working memory and numerical processing efficiency. Additional studies in the Indonesian context also support these findings, showing that kinesthetic approaches can improve student engagement and conceptual understanding (Kim, M., & Park, 2018). Recent international studies further reinforce the role of finger-based strategies in early numeracy development. The use of finger counting and gesture-based representations has been shown to support the acquisition of fundamental numerical concepts and improve arithmetic performance among young learners (Fischer, 2020; Morrissey, 2020). Moreover, recent findings emphasize that finger counting should not be viewed as a limitation, but rather as a meaningful developmental strategy that supports cognitive processing and mathematical understanding (Krenger, 2025).

In line with previous findings, several studies have shown that elementary students' numeracy literacy still exhibits a gap between conceptual understanding and practical performance. This condition highlights the need for more contextual and diagnostic learning approaches to more accurately identify students' learning difficulties (Rakhmawati & Mustadi, 2022). In addition, the use of interactive and innovative learning media has been proven to enhance both conceptual understanding and student engagement, particularly for those experienciatics (Patricia & Zamzam, 2021). Furthermore, recent studies emphasize that improving numeracy competence requires systematic and innovative instructional interventions (Dikdik et al., 2025). Therefore, implementing kinesthetic-based approaches, such as finger math, combined with diagnostic assessments based on accuracy and speed, is essential to provide a more comprehensive understanding of students' numeracy abilities.

Finger-based strategies have been shown to support early numeracy development, particularly for lower-performing students, by strengthening numerical representation and cognitive processing (Elgavi, 2025; Kovarsky Rotta, 2026). This is consistent with broader evidence suggesting that learning approaches grounded in psychological and cognitive principles, including embodied and interactive strategies, can significantly improve students' arithmetic performance and engagement (Boussaha, 2025). In addition, targeted interventions focusing on arithmetic fluency have also been shown to effectively improve basic mathematical skills among struggling elementary students (Karnes, 2021).

However, while the present findings align with previous research, they also extend existing studies. Most prior research has primarily focused on accuracy as a single indicator of numeracy performance. In contrast, this study demonstrates that integrating accuracy and speed provides a more comprehensive understanding of students' numeracy abilities. This suggests that numeracy assessment should not be limited to correctness alone but should also consider processing efficiency as an essential component of mathematical competence.

From a pedagogical perspective, the effectiveness of finger math may also be attributed to its alignment with the developmental characteristics of early-grade learners. At this stage, students are still transitioning from concrete to abstract thinking, making kinesthetic and visual supports essential for meaningful learning. The use of finger-based strategies allows students to externalize their thinking processes, thereby facilitating both conceptual understanding and procedural fluency.

From a broader educational perspective, 21st-century numeracy requires not only conceptual understanding but also efficiency and flexibility in applying mathematical skills in authentic real-life situations. In this regard, the finger math method is considered relevant because it simultaneously develops accuracy and speed, which are important indicators of numeracy competence (Voskoglou, 2020).

The findings of this study also have important implications for diagnostic assessment. The simultaneous analysis of accuracy and speed enables the identification of diverse learning profiles. Students who demonstrate high accuracy and high speed have well-developed conceptual understanding and automaticity. In contrast, students with high accuracy but low speed may require additional practice to improve fluency, while those with high speed but low accuracy may need support to strengthen conceptual understanding and reduce impulsive errors. Students with low performance in both aspects require more intensive intervention. These profiles provide valuable information for teachers in designing targeted instructional strategies.

Despite these contributions, this study has several limitations that should be acknowledged. First, the use of purposive sampling and non-random group assignment may limit the generalizability of the findings (Gopalan, 2020). Second, the study was conducted in a specific local context, namely Islamic elementary schools in North Sulawesi, which may not represent broader educational settings. Third, the absence of a pretest limits the ability to fully establish baseline equivalence between groups, potentially introducing bias in interpreting the results.

Therefore, future research is recommended to employ more rigorous experimental designs, such as randomized controlled trials, and to involve larger and more diverse samples. Further studies could also explore the longitudinal effects of finger math on numeracy development and examine its applicability across different educational contexts and grade levels.

In practical terms, the findings suggest that the finger math method can be effectively implemented as both a learning strategy and a diagnostic tool in elementary mathematics education. Teachers are encouraged to integrate kinesthetic-based approaches into classroom instruction to support students' understanding and engagement. Additionally, the use of diagnostic assessments based on accuracy and speed can assist teachers in identifying students' learning needs more precisely and in designing more adaptive, targeted instructional interventions.

Conclusion

The results of this study indicate that the application of the finger math method significantly improves the numeracy skills of private Islamic elementary school students, particularly in Phase A, in terms of both calculation accuracy and speed. Compared with conventional learning, students who used finger math demonstrated higher accuracy and faster problem-solving times, reflecting more efficient, automated arithmetic processing during early numeracy learning. Descriptively, students in the finger math group demonstrated higher accuracy and faster completion times than those in the conventional group. These findings suggest that finger math has potential as an effective learning strategy and may also serve as an initial diagnostic approach for mapping students' numeracy profiles more comprehensively.

This study contributes to the development of mathematics education by emphasizing the importance of integrating accuracy and speed as complementary indicators in diagnostic assessment. The combination of these two aspects provides a more comprehensive understanding of students' numeracy ability profiles, including conceptual understanding and cognitive processing efficiency. From a practical perspective, these findings suggest that the finger math method can be implemented not only as a learning strategy but also as a diagnostic tool in elementary mathematics classrooms. Teachers can use this approach to identify students' learning difficulties more precisely and to design targeted instructional interventions, particularly for early-grade learners who benefit from kinesthetic and concrete learning experiences.

However, several limitations should be acknowledged. The use of purposive sampling and non-random group assignment may limit the generalizability of the findings. In addition, the study was conducted in a specific local context, and the absence of a pretest may affect the interpretation of baseline equivalence between groups. Therefore, future research is recommended to employ more rigorous experimental designs, such as randomized controlled trials, and to involve larger and more diverse samples. Further studies may also explore the long-term impact of finger math and examine its effectiveness across different educational contexts and grade levels.

References

Baird, J. A., Andrich, D., Hopfenbeck, T. N., & Stobart, G. (2017). Assessment and learning: Fields apart? *Assessment in Education: Principles, Policy & Practice*, *24*(3), 317–350. DOI: https://doi.org/10.1080/0969594X.2017.1319337

Baroody, A. J. (2006). Why children have difficulties mastering the basic number combinations and how to help them. *Teaching Children Mathematics*, *13*(1), 22–31. DOI: https://doi.org/10.5951/TCM.13.1.0022

Boussaha, K. (2025). Towards a new generation of digital games designed with the basics of psychological theories to improve primary school pupils' psychological and technical skills in learning arithmetic. *Entertainment Computing*, *53*, 100927. DOI: https://doi.org/10.1016/j.entcom.2025.100927

Carbonneau, K. J., Marley, S. C., & Selig, J. P. (2013). A meta-analysis of the efficacy of teaching mathematics with concrete manipulatives. *Journal of Educational Psychology*, *105*(2), 380–400. DOI: https://doi.org/10.1037/a0031084

Dikdik, A., Suryana, A., Triana, C., Rahyasih, Y., & Oktaviani, F. F. (2025). Improving teachers' numeracy skills at Cisarua State Elementary School, West Java, Indonesia. *Jurnal Prima Edukasia*, *13*(1), 111–127. DOI: https://doi.org/10.21831/jpe.v13i1.82453

Elgavi, O., & Osana, H. P. (2025). Math on the brain: Seven principles from neuroscience for early childhood educators. *Early Childhood Education Journal*. DOI: https://doi.org/10.1007/s10643-024-01656-2

Finch, W. H. (2022). Multivariate analysis of variance for multilevel data: A simulation study comparing methods. *The Journal of Experimental Education*, *90*(1), 173–190. DOI: https://doi.org/10.1080/00220973.2020.1718058

Fischer, U., Moeller, K., Bientzle, M., Cress, U., & Nuerk, H. C. (2011). Sensori-motor spatial training of number magnitude representation. *Psychonomic Bulletin & Review*, *18*(1), 177–183. DOI: https://doi.org/10.3758/s13423-010-0031-3

Fischer, U., Moeller, K., Bientzle, M., Cress, U., & Nuerk, H.-C. (2020). The implicit contribution of fine motor skills to mathematical insight. *Frontiers in Psychology*, *11*, 1143. DOI: https://doi.org/10.3389/fpsyg.2020.01143

Garcia-Perez, A., & Nunez-Anton, V. (2021). A comprehensive review of MANOVA procedures and their application in educational research. *Mathematics*, *9*(15), 1811. DOI: https://doi.org/10.3390/math9151811

Geary, D. C. (2011). Cognitive predictors of achievement growth in mathematics: A 5-year longitudinal study. *Developmental Psychology*, *47*(6), 1539–1552. DOI: https://doi.org/10.1037/a0025510

Gopalan, M., Rosinger, K., & Ahn, J. B. (2020). Use of quasi-experimental research designs in education research: Growth, promise, and challenges. *Review of Research in Education*, *44*(1), 218–243. DOI: https://doi.org/10.3102/0091732X20903302

Haenilah, E. Y., Ridwan, & Hariri, H. (2023). Scientific method-based pedagogical competence reflection for improving teacher professionalism. *Journal of Educational and Social Research*, *13*(5), 265–276. DOI: https://doi.org/10.36941/jesr-2023-0136

Jonas, N. (2018). Numeracy practices and numeracy skills among adults. *OECD Education Working Papers*, *177*, 1–83. DOI: https://doi.org/10.1787/8f19fc9f-en

Karim, S., & Indra, M. (2025). Improving vocational students' learning outcomes through an innovative instructional model: A quasi-experimental study. *Jurnal Pendidikan Vokasi*, *15*(3). DOI: https://doi.org/10.21831/jpv.v15i3.77430

Karnes, J., Boyd, A., & Grant, M. (2021). The effects of a math racetracks intervention on the single-digit multiplication facts fluency of four struggling elementary school students. *Insights into Learning Disabilities*, *18*(1), 53–77. https://www.ldw-ild.org/images/Karnes_Barwasser_Grnke_2021.pdf

Kim, M., & Park, J. (2018). The effects of finger calculation strategies on students' basic calculation ability. *Journal of Educational Psychology Research*, *36*(2), 145–158.

Kovarsky Rotta, G., & Leme, C. E. (2026). A handy tool: Using fingers as a numerical representation specifically benefits lower performers in kindergarten mathematics. *Developmental Psychology*. DOI: https://doi.org/10.1037/dev0002032

Krenger, M., & Thevenot, C. (2025). Finger counting is not a dead end: It supports the development of efficient calculation strategies. *Journal of Cognition and Development*. DOI: https://doi.org/10.1080/15248372.2025.2606280

Lafay, A., Osana, H. P., & Levin, J. R. (2023). Does conceptual transparency in manipulatives afford place-value understanding in children at risk for mathematics learning disabilities? *Learning Disability Quarterly*, *46*(2), 87–101. DOI: https://doi.org/10.1177/07319487221124088

Liu, J., Bulut, O., & Johnson, M. D. (2024). Examining position effects on students' ability and test-taking speed in the TIMSS 2019 problem-solving and inquiry tasks: A structural equation modeling approach. *Psychology International*, *6*(2), 492–508. DOI: https://doi.org/10.3390/psycholint6020030

Moeller, K., Martignon, L., Wessolowski, S., Engel, J., & Nuerk, H. (2012). Effects of finger-based training on numerical skills in preschoolers. *Developmental Science*, *15*(6), 875–885. DOI: https://doi.org/10.1111/j.1467-7687.2012.01185.x

Morrissey, K., Liu, Y., & Ding, M. (2020). Finger-counting habits in arithmetic and their relation to mathematical performance. *Psychological Research*, *84*(8), 2180–2191. DOI: https://doi.org/10.1007/s00426-018-0990-y

Neveu, M., Geurten, M., Durieux, N., & Rousselle, L. (2023). Finger use and arithmetic skills in children and adolescents: A scoping review. *Educational Psychology Review*, *35*(2), Article 51. DOI: https://doi.org/10.1007/s10648-023-09722-8

Panadero, E., Andrade, H., & Brookhart, S. M. (2018). Fusing self-regulated learning and formative assessment: A roadmap of where we are, how we got here, and where we are going. *The Australian Educational Researcher*, *45*(1), 13–31. DOI: https://doi.org/10.1007/s13384-018-0258-y

Patricia, F. A., & Zamzam, K. F. (2021). Development of scientific approach-based interactive multimedia for elementary school dyscalculia children. *Jurnal Prima Edukasia*, *9*(1), 103–113. DOI: https://doi.org/10.21831/jpe.v9i1.33853

Poletti, C., Krenger, M., Létang, M., & Thevenot, C. (2023). French preschool and primary teachers' attitude towards finger counting. *Acta Psychologica*, *241**, 104079. DOI: https://doi.org/10.1016/j.actpsy.2023.104079

Ponte, R., Viseu, F., Neto, T. B., & Aires, A. P. (2023). Revisiting manipulatives in the learning of geometric figures. *Frontiers in Education*, *8*, 1217680. DOI: https://doi.org/10.3389/feduc.2023.1217680

Powell, S. R., Berry, K. A., & Barnes, M. A. (2022). Achievement in arithmetic and pre-algebraic reasoning: Relations with mathematics problem solving. *Learning and Individual Differences*, *97*, 102157. DOI: https://doi.org/10.1016/j.lindif.2022.102157

Rakhmawati, Y., & Mustadi, A. (2022). The circumstances of literacy numeracy skill: Between notion and fact from elementary school students. *Jurnal Prima Edukasia*, *10*(1), 9–18. DOI: https://doi.org/10.21831/jpe.v10i1.36427

Roy, E., Guillaume, M., Van Rinsveld, A., & McCandliss, B. D. (2025). Tablet-based arithmetic fluency assessment reveals developments in math cognition and math achievement from childhood to adolescence. *npj Science of Learning*, *10*(19). DOI: https://doi.org/10.1038/s41539-025-00314-5

Sweller, J., Ayres, P., & Kalyuga, S. (2011). *Cognitive load theory*. Springer. DOI: https://doi.org/10.1007/978-1-4419-8126-4

Tout, D., Safford-Ramus, K., & Misztal, B. (2021). Numeracy, adult education, and vulnerable adults: A critical view of a neglected field. *ZDM–Mathematics Education*, *53*(3), 475–489. DOI: https://doi.org/10.1007/s11858-021-01227-8

Voskoglou, M. G., & Salem, A. B. M. (2020). Benefits and challenges of the artificial intelligence applications in education. *Advances in Intelligent Systems and Computing*, *902*, 804–811. DOI: https://doi.org/10.1007/978-3-030-11932-4_75

Wijaya, A., van den Heuvel-Panhuizen, M., & Doorman, M. (2015). Opportunity-to-learn context-based tasks provided by mathematics textbooks. *Educational Studies in Mathematics*, *89*(1), 41–65. DOI: https://doi.org/10.1007/s10649-015-9595-1