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Research Article

The Role of Executive Functions in Early Mathematics Achievement: A Cognitive Psychology Perspective

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Abstract

Early mathematics achievement is a critical predictor of long-term academic success, and understanding the cognitive mechanisms underlying mathematical learning is essential for educational psychology. Executive functions (EF) including working memory, inhibitory control, and cognitive flexibility play a pivotal role in supporting problem-solving, numerical reasoning, and the acquisition of mathematical concepts. This study aims to examine the contribution of executive functions to early mathematics achievement from a cognitive psychology perspective. A mixed-methods approach was employed, combining standardized EF assessments with mathematics performance tests in a sample of children aged 5-7 years. Data were analyzed using correlational and regression techniques to determine the predictive power of specific executive function components. Results indicate that working memory and inhibitory control are strongly associated with early numeracy skills, while cognitive flexibility contributes to adaptive problem-solving in novel mathematical tasks. Children with higher EF scores demonstrated significantly better performance in arithmetic, pattern recognition, and applied problem-solving. The study concludes that integrating EF training into early education curricula could provide a foundation for sustained mathematical competence and cognitive growth.

Keywords: Early Mathematics, Executive Functions, Working Memory

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INTRODUCTION

Early mathematics achievement has been widely recognized as a crucial determinant of long-term academic and cognitive development. Cognitive psychologists have emphasized that mathematical skills acquired during the early years of schooling serve as foundational building blocks for later learning in diverse disciplines (Kenny et al., 2023; Ng et al., 2021). Early numeracy not only shapes proficiency in mathematics but also supports logical reasoning, problem-solving abilities, and the acquisition of complex cognitive skills. Developmental studies suggest that the acquisition of basic mathematical competencies is strongly intertwined with cognitive processes that underlie attention, memory, and self-regulation. Understanding the factors that influence early mathematics achievement, therefore, becomes essential for designing effective educational interventions and informing curriculum development in early childhood education. Executive functions, as a set of high-level cognitive processes, play a central role in guiding thought and behavior towards goal-directed outcomes (H Migueles et al., 2021; Wang et al., 2022). Core components of executive functions include working memory, inhibitory control, and cognitive flexibility, all of which contribute to a child's ability to process information, regulate behavior, and adapt to novel problem-solving scenarios. Research in cognitive psychology indicates that children who possess stronger executive function skills tend to exhibit higher proficiency in tasks requiring attention, numerical reasoning, and multi-step problem-solving. The dynamic interaction between executive functions and early mathematics performance has emerged as a critical area of inquiry, highlighting the importance of understanding cognitive mechanisms that support mathematical learning.

Recent interdisciplinary research has explored how executive functions mediate early academic achievement, particularly in mathematics. Empirical evidence suggests that individual differences in working memory and inhibitory control may account for variability in numerical skill acquisition. Cognitive flexibility, another key executive function, enables learners to shift between strategies, adapt to new mathematical contexts, and engage in higher-order reasoning (Curenton et al., 2022; Wang et al., 2022). Despite increasing attention, the relationship between executive functions and early mathematics achievement remains complex and partially understood, requiring further investigation to inform theory, practice, and policy in educational psychology and early childhood pedagogy. Despite growing recognition of the importance of executive functions, many children continue to struggle with basic mathematical skills during the early years of formal education. Performance gaps in numeracy emerge as early as kindergarten and first grade, with long-term consequences for academic trajectories and future STEM learning opportunities. Research has consistently documented that difficulties in mathematics are often accompanied by weaknesses in executive functions, suggesting that deficits in working memory, inhibitory control, or cognitive flexibility may impede the learning of foundational arithmetic and problem-solving skills. Identifying specific cognitive mechanisms that contribute to these difficulties is essential for developing targeted interventions to support early learners.

The lack of systematic integration between cognitive assessments and early mathematics curricula presents another challenge for educators and researchers. Traditional instructional approaches often emphasize rote memorization and procedural fluency without considering the underlying cognitive capacities required for problem-solving and adaptive reasoning (Bakar et al., 2025; Perichon et al., 2025). Consequently, children with limited executive function skills may experience frustration, reduced motivation, and slower learning trajectories. This gap between educational practice and cognitive science understanding underscores the need for research that bridges theory and application, highlighting mechanisms that directly influence early mathematical outcomes. Variability in executive function development further complicates the problem, as children exhibit considerable differences in working memory capacity, inhibitory control efficiency, and cognitive flexibility even within the same age group (Bakar et al., 2025; Perichon et al., 2025). These individual differences have significant implications for early mathematics achievement, as learners with stronger executive functions may engage more effectively in complex cognitive tasks, while those with weaker skills face persistent challenges. Understanding the nature of these cognitive differences and their impact on numeracy provides a focused rationale for investigating the role of executive functions in early mathematics achievement from a cognitive psychology perspective.

The primary aim of this research is to examine the influence of executive functions on early mathematics achievement, providing a detailed cognitive psychology perspective on the underlying mechanisms (Bachman et al., 2022; Michel et al., 2024). Specific objectives include identifying which components of executive functions working memory, inhibitory control, and cognitive flexibility are most predictive of mathematical proficiency in young learners. The study seeks to quantify the relationships between executive function skills and numeracy outcomes, offering insights into how cognitive processes support or hinder early mathematics development. Another objective is to explore the interaction between different executive function components and specific mathematical domains, such as arithmetic, pattern recognition, and problem-solving. By mapping these relationships, the research intends to clarify the cognitive pathways that facilitate or constrain learning, thereby enabling the design of targeted interventions and instructional strategies.

This investigation will provide empirical evidence to guide educators in adapting teaching practices to the diverse cognitive profiles of early learners (Ahmed et al., 2021; Akhavein et al., 2025). Additionally, the study aims to inform policy and curriculum design in early childhood education by emphasizing the importance of integrating executive function development with mathematics instruction. Outcomes from this research are expected to support evidence-based recommendations for enhancing cognitive readiness, promoting adaptive learning strategies, and fostering long-term academic success. The ultimate goal is to contribute to a more nuanced understanding of how executive functions underpin early mathematical competence, bridging the gap between cognitive theory and educational practice.

Existing literature has extensively documented correlations between executive functions and academic achievement, but research specifically linking executive functions to early mathematics outcomes remains limited. Many studies focus on general cognitive ability or broad academic performance, neglecting the nuanced contributions of specific executive function components to numeracy skills (Ahmed et al., 2021; Whitehead & Hawes, 2023). This lack of targeted investigation leaves unanswered questions regarding which cognitive processes are most critical for early mathematics achievement and how they interact with age, instructional context, and individual differences. Previous interventions aimed at improving early mathematics performance often emphasize procedural learning, drill-based exercises, and skill repetition without addressing underlying cognitive mechanisms. Consequently, research integrating cognitive psychology frameworks with educational interventions is sparse (Ernst et al., 2025; Whitehead & Hawes, 2023). There is a pressing need for studies that investigate the causal and predictive relationships between executive functions and mathematics performance, offering insights into how cognitive development can be leveraged to enhance educational outcomes. Empirical studies to date have produced mixed results regarding the relative importance of working memory, inhibitory control, and cognitive flexibility in supporting early numeracy. Differences in methodology, sample characteristics, and assessment tools contribute to inconsistent findings, limiting generalizability and practical application (Salem et al., 2023; Vanhala et al., 2024). This study seeks to address these gaps by providing a comprehensive, theoretically grounded analysis of executive function contributions to early mathematics achievement, advancing both scientific understanding and pedagogical practice.

This research offers a novel contribution by examining early mathematics achievement through a cognitive psychology lens, emphasizing the role of executive functions as critical determinants of numeracy skills (Salem et al., 2023; Vanhala et al., 2024). Unlike prior studies that focus solely on academic performance or general cognitive ability, this study disaggregates executive function components to determine their specific predictive power. The approach allows for a more precise understanding of how working memory, inhibitory control, and cognitive flexibility uniquely contribute to mathematical learning in early childhood. Justification for this research lies in its potential to inform educational practice and intervention design. By identifying the cognitive processes that underlie early mathematics achievement, educators can develop strategies that not only enhance numeracy but also strengthen foundational executive function skills.

This integration of cognitive theory with applied pedagogy addresses a key need in early childhood education, providing actionable insights for curriculum development and instructional planning. Furthermore, the study contributes to theory building in cognitive psychology by elucidating the mechanisms through which executive functions influence academic outcomes. The findings are expected to advance interdisciplinary scholarship, connecting developmental psychology, educational research, and cognitive neuroscience (Fricke et al., 2023; Salem et al., 2023). The research establishes a foundation for future investigations on targeted interventions, adaptive learning technologies, and evidence-based pedagogical innovations that support cognitive and academic development from an early age.

RESEARCH METHOD

This study adopted a quantitative methodological framework to investigate the association between executive functions and early mathematics achievement among young children in primary education settings. A correlational perspective was utilized to explore how cognitive processes influence children's numeracy development and academic readiness in mathematics (Coolen et al., 2021; Gillet et al., 2021). The research emphasized the role of executive functioning components, including working memory, inhibitory control, and cognitive flexibility, in supporting mathematical reasoning and problem-solving abilities during early childhood. Through systematic measurement and statistical examination, the study aimed to generate empirical evidence concerning the cognitive predictors of early mathematics performance within the context of developmental and cognitive psychology.

Research Design

The research employed a quantitative correlational design to determine the extent to which executive functions are associated with early mathematics achievement in young learners. This design was considered appropriate because it enabled the researcher to identify patterns, relationships, and predictive contributions among cognitive and academic variables without manipulating the study environment (Coolen et al., 2021; Gillet et al., 2021). The correlational approach also provided an objective framework for examining whether variations in executive functioning skills could significantly explain differences in numeracy outcomes among children. By utilizing structured statistical procedures, the study generated evidence-based interpretations regarding the interaction between executive cognitive processes and mathematical competence in early education contexts.

Research Target/Subject

The target population consisted of children between 5 and 7 years old who were enrolled in early primary education programs located in both urban and suburban schools. A purposive sampling strategy was implemented to recruit 120 participants who satisfied predetermined inclusion criteria, such as having typical cognitive development and maintaining consistent school attendance (Ribeiro et al., 2022; Watanabe, 2021). Furthermore, the sample was organized using stratification procedures to ensure proportional representation in terms of age, gender, and socioeconomic background. This sampling strategy was intended to provide a heterogeneous dataset that could adequately reflect individual differences in executive functioning and early mathematics achievement among young learners.

Research Procedure

The research procedure began with obtaining ethical approval and securing informed consent from parents or guardians, as well as assent from participating children. After administrative permissions were granted by the selected schools, participants underwent individual assessment sessions conducted in quiet and controlled classroom environments to minimize distractions. During the sessions, each child completed a sequence of executive function tasks before proceeding to standardized mathematics assessments. Trained researchers supervised and recorded participant performance throughout the testing process to maintain procedural consistency and accuracy. Ethical principles, including confidentiality, voluntary participation, and participant anonymity, were strictly maintained during all stages of the study (H. Zhang et al., 2023; Zhu et al., 2025).

Instruments and Data Collection Techniques

Data collection was carried out using standardized and age-appropriate assessment instruments designed to evaluate executive functions and early mathematics achievement. Executive functioning abilities were measured through tasks assessing working memory, inhibitory control, and cognitive flexibility, while numeracy competence was evaluated using mathematics tests covering arithmetic understanding, pattern identification, and applied problem-solving skills (Nakamichi et al., 2022; H. Zhang et al., 2023). The selected instruments possessed established validity and reliability for young children, ensuring consistency and precision in data measurement. Data were collected through direct individual testing sessions within the participants' schools, where trained assessors administered all instruments systematically according to standardized procedures.

Data Analysis Technique

The collected data were analyzed quantitatively using descriptive and inferential statistical techniques. Descriptive statistics were first applied to summarize participant characteristics and overall performance patterns in executive functions and mathematics achievement. Subsequently, correlation analysis was conducted to identify the strength and direction of relationships between executive functioning components and numeracy outcomes.

Multiple regression analysis was then employed to examine the predictive contribution of working memory, inhibitory control, and cognitive flexibility toward early mathematics achievement. These analytical procedures enabled the study to provide a comprehensive explanation of how executive cognitive processes contribute to numeracy development among young learners.

RESULTS AND DISCUSSION

Descriptive statistics were computed to summarize participants' performance on executive function tasks and early mathematics assessments. Mean scores, standard deviations, and ranges were calculated for each variable. Table 1 presents an overview of the descriptive data, including working memory, inhibitory control, cognitive flexibility, and overall mathematics achievement. Working memory scores ranged from 15 to 28, with a mean of 21.3 (SD = 3.2). Inhibitory control had a mean of 19.7 (SD = 3.5), while cognitive flexibility scores averaged 20.5 (SD = 3.1). Early mathematics achievement exhibited a mean of 42.8 (SD = 6.7) on a standardized numeracy test with a range of 30 to 60.

Table 1. Descriptive Statistics of Executive Functions and Early Mathematics Achievement

Variable	Mean	SD	Minimum
Working Memory	21.3	3.2	15
Inhibitory Control	19.7	3.5	13
Cognitive Flexibility	20.5	3.1	14
Mathematics Achievement	42.8	6.7	30

Analysis of the descriptive data indicates that participants displayed a moderate level of executive function skills and numeracy performance. Distributions were approximately normal across all measures, suggesting suitability for further inferential statistical analysis. Variation in executive function scores reflects individual differences that may influence mathematics learning outcomes. Working memory appeared to have a particularly strong relationship with arithmetic performance. Children with higher working memory scores demonstrated superior accuracy in multi-step problems and pattern recognition tasks. Inhibitory control was associated with fewer calculation errors, suggesting that the ability to suppress impulsive responses enhances precise execution of numerical operations. Cognitive flexibility contributed to adaptive problem-solving, allowing participants to switch strategies when encountering novel or complex tasks. Interpreting these findings reveals the cognitive mechanisms by which executive functions support early mathematics. Higher working memory enables simultaneous processing of numerical information, while effective inhibitory control prevents distractions from disrupting task performance. Cognitive flexibility allows students to approach problems creatively, improving problem-solving efficiency. Collectively, these components facilitate a foundation for developing higher-order mathematical reasoning.

A subset of participants exhibited high variability in executive function profiles. Some children demonstrated strong working memory but weaker inhibitory control, whereas others showed balanced performance across all domains. Mathematics achievement scores corresponded closely to these profiles, with individuals demonstrating robust executive functions achieving higher numeracy scores. Analysis of central tendency and dispersion highlighted the differential contributions of executive function components to mathematics performance. These patterns suggest that not all executive functions contribute equally to numeracy. Working memory emerged as the strongest predictor, followed by cognitive flexibility, while inhibitory control exhibited a moderate effect. Differences across participants underscore the importance of considering individual cognitive profiles when designing instructional interventions. Multiple regression analysis was conducted to determine the predictive power of executive functions on mathematics achievement. Working memory ($\beta = 0.42$, $p < 0.001$), inhibitory control ($\beta = 0.29$, $p < 0.01$), and cognitive flexibility ($\beta = 0.31$, $p < 0.01$) collectively accounted for 56% of the variance in early mathematics performance ($R^2 = 0.56$). This indicates that executive function skills significantly influence numeracy outcomes in young learners.

Further correlation analyses revealed positive, significant relationships among executive function components and mathematics achievement. Working memory correlated most strongly with arithmetic problem-solving ($r = 0.64$, $p < 0.001$), cognitive flexibility was associated with adaptive reasoning ($r = 0.52$, $p < 0.01$), and inhibitory control showed a moderate correlation with calculation accuracy ($r = 0.48$, $p < 0.01$). These findings support the hypothesis that executive functions are key determinants of early numeracy competence. Relationships among the variables suggest an interactive effect of executive functions on mathematics achievement. Participants with high working memory and cognitive flexibility scores performed optimally across multiple numerical domains. Inhibitory control appeared to moderate the impact of working memory by reducing errors in high-load tasks. These relational patterns highlight the interdependence of executive function components in supporting early mathematics learning. Pattern analysis indicates that children with imbalanced executive function profiles often struggled with tasks requiring multi-step reasoning or strategy shifts. Conversely, those with balanced executive functions demonstrated consistent performance across problem types. Understanding these relationships can inform tailored interventions targeting specific cognitive deficits to enhance numeracy outcomes.

A case study of a 6-year-old participant illustrates the interplay of executive functions and mathematics performance. The child exhibited high working memory (score = 27), moderate inhibitory control (score = 19), and strong cognitive flexibility (score = 25). Mathematics assessment revealed high accuracy in arithmetic tasks, quick problem-solving in pattern recognition, and successful application of novel strategies in word problems. Observational notes recorded focused attention and adaptive approach to challenging questions. The case demonstrates that strong executive function skills support effective numeracy performance, particularly in tasks requiring multi-step reasoning and cognitive flexibility. Differences in inhibitory control appeared compensated by robust working memory and flexibility, highlighting the compensatory mechanisms within executive function components that facilitate early mathematics achievement. Case observations reveal that executive function strengths directly influence task engagement and problem-solving approaches. High working memory allowed the child to retain multiple numerical elements, while cognitive flexibility enabled strategy adaptation. Inhibitory control facilitated sustained focus, reducing careless errors. The integrated effect of these functions led to superior mathematics achievement compared to peers with weaker executive function profiles.

The data underscores the theoretical proposition that executive functions underpin cognitive readiness for numeracy (Núñez et al., 2024; Zhu et al., 2025). Children with well-developed executive functions can process complex information, inhibit distractions, and flexibly adapt strategies, resulting in measurable gains in early mathematics performance.

Overall results suggest that executive functions are significant predictors of early mathematics achievement. Working memory emerges as the primary contributor, followed by cognitive flexibility and inhibitory control, collectively accounting for a substantial proportion of variance in numeracy skills. Findings confirm cognitive psychology theories emphasizing the foundational role of executive functions in supporting early learning. Interpretation highlights practical implications for early education, suggesting that interventions focusing on enhancing executive function skills can improve mathematical outcomes. Educators may integrate activities that strengthen memory, self-regulation, and flexible thinking to foster holistic cognitive development and support early numeracy (Duncan et al., 2023; Morgan et al., 2024). The study demonstrated that executive functions, particularly working memory, inhibitory control, and cognitive flexibility, are significant predictors of early mathematics achievement in children aged 5 to 7 years. Working memory showed the strongest correlation with arithmetic performance and multi-step problem-solving tasks. Inhibitory control contributed to greater accuracy in calculations by enabling children to suppress impulsive responses, while cognitive flexibility facilitated adaptive strategy use in novel problem-solving situations. Multiple regression analysis indicated that these executive function components collectively accounted for 56% of the variance in early numeracy scores, highlighting their critical role in shaping early mathematical competence.

Observation and case study data further supported the quantitative results. Children with balanced and strong executive function profiles consistently performed well across arithmetic, pattern recognition, and applied problem-solving tasks. Variations in individual executive function strengths corresponded to differential performance levels, suggesting that each component contributes uniquely to early numeracy outcomes (Nanova et al., 2024; Reitano, 2024). The study provides empirical evidence for the integral role of cognitive processes in early mathematics development, confirming theoretical assertions from cognitive psychology regarding the importance of higher-order executive processes in academic achievement. Descriptive data analysis revealed moderate to high levels of executive function skills among participants, with substantial variability across individuals. This variation underscores the necessity of considering cognitive profiles when interpreting early mathematics performance and designing instructional strategies. The findings emphasize that early mathematics achievement is not solely dependent on teaching methods or rote memorization but is closely linked to the cognitive readiness of learners. The combined evidence from statistical analysis, correlation patterns, and observational insights supports the conclusion that executive functions are foundational to early numeracy development. Children who possess strong executive function capacities demonstrate enhanced engagement, error management, and adaptive problem-solving, resulting in measurable improvements in mathematics performance. This highlights the cognitive underpinnings that contribute to successful early learning experiences.

Findings align with previous research demonstrating the predictive power of executive functions in early academic achievement. Studies by (Bleses et al., 2023; J. Zhang et al., 2025) similarly reported strong associations between working memory and early numeracy skills, confirming that cognitive processes are central to arithmetic and problem-solving performance. The present study extends these findings by providing detailed analysis of inhibitory control and cognitive flexibility, showing that these components not only support calculation accuracy but also facilitate strategic adaptation in novel tasks. Differences emerged when compared with research focusing primarily on working memory. Some prior studies, such as those by Alloway and Alloway (2010), emphasized working memory as the dominant predictor while downplaying the contributions of inhibitory control and cognitive flexibility. In contrast, this study demonstrates that inhibitory control and flexibility also play meaningful roles, albeit secondary to working memory. The inclusion of case study observations offers additional qualitative insights that complement quantitative analyses, providing a more holistic understanding of executive function interactions.

The results partially contrast with research conducted in different cultural contexts, where variations in early numeracy curricula and pedagogical approaches influenced the relative importance of specific executive function components. In Southeast Asian educational settings, for example, working memory may be particularly engaged due to curriculum emphasis on multi-step problem-solving, while inhibitory control assumes greater importance in classroom settings with higher peer distractions. These contextual differences highlight the need to consider environmental and cultural factors when interpreting executive function contributions. Integration of the current findings with prior literature strengthens the theoretical framework of cognitive psychology by demonstrating that early mathematics achievement is a multi-faceted construct influenced by interrelated executive processes. The study underscores the importance of examining all core executive function components rather than focusing narrowly on a single skill. This nuanced understanding provides a clearer basis for developing effective interventions and instructional strategies. The results indicate that early mathematics achievement reflects underlying cognitive readiness and executive function maturity. Children's ability to retain numerical information, control impulses, and shift strategies effectively signals their capacity for higher-order learning. Executive function development is therefore a critical factor that educators and psychologists must consider when assessing early numeracy potential.

Observations of individual differences suggest that uneven development of executive function components may manifest as specific learning challenges. For instance, a child with strong working memory but weak inhibitory control may excel in calculation but struggle with maintaining attention or avoiding errors. These patterns reflect the complex interplay between cognitive capacities and learning outcomes, highlighting the need for individualized assessment (Brunner et al., 2024; Martin-Requejo et al., 2023). The findings also signify that early mathematics performance is not merely an outcome of environmental exposure or rote practice but is intricately linked to neurocognitive development. Cognitive readiness and executive function skills provide the foundation upon which formal numeracy instruction builds. Enhancing these capacities may therefore accelerate learning and improve long-term academic trajectories. Reflection on the results underscores the significance of integrating cognitive psychology principles into early education. Early identification of executive function strengths and weaknesses can guide pedagogical decisions, ensuring that children receive targeted support to optimize both their cognitive and mathematical development. This perspective repositions early mathematics achievement as an indicator of broader cognitive competence.

The study has direct implications for educational practice, emphasizing the importance of embedding executive function training within early mathematics instruction. Interventions designed to strengthen working memory, inhibitory control, and cognitive flexibility can enhance numerical learning outcomes and prepare children for more complex mathematical tasks in later grades. Schools and educators may adopt evidence-based activities such as memory games, strategic problem-solving exercises, and self-regulation training to support executive function development. Curriculum design can benefit from the integration of cognitive psychology insights, aligning instructional sequences with children's executive function capabilities. Tailored strategies that scaffold working memory demands and promote adaptive problem-solving can create more effective learning environments. This approach ensures that instruction accommodates cognitive variability among learners, maximizing engagement and achievement. Policy implications include the recommendation for early assessment of executive function as part of routine educational evaluation. Identifying children with executive function delays can facilitate early interventions that prevent long-term academic difficulties, particularly in numeracy. Resources can be allocated to training teachers in recognizing and supporting executive function development alongside mathematics instruction. Implications extend to educational research, highlighting the need for interdisciplinary approaches combining cognitive psychology, neuroscience, and pedagogy. Understanding the cognitive mechanisms underpinning early mathematics achievement enables the development of innovative instructional tools, digital interventions, and adaptive learning technologies that cater to diverse learner needs.

Findings reflect the inherent role of executive functions in cognitive processing and problem-solving. Working memory allows children to retain numerical information and apply it across multiple steps, inhibitory control prevents errors caused by distraction or impulsivity, and cognitive flexibility supports adaptive strategy selection when encountering novel problems. These processes are fundamental to learning mathematics. Neurodevelopmental factors contribute to variability in executive function maturation. Individual differences in prefrontal cortex development may explain why some children demonstrate stronger working memory or inhibitory control, directly affecting their mathematics achievement. Environmental factors, such as classroom structure and instructional style, interact with these neurocognitive capacities to shape learning outcomes. Curricular exposure and practice also influence executive function application. Children engaged in structured problem-solving tasks and cognitively demanding activities are likely to exhibit better-developed executive functions, translating into higher early numeracy performance. Educational environments that encourage attention, strategic thinking, and flexibility reinforce these cognitive skills. The study's context-specific factors, including age, prior knowledge, and classroom setting, further explain the observed patterns. Executive function contributions vary depending on task complexity, instructional methods, and peer interactions, emphasizing that mathematics achievement is a product of dynamic cognitive, educational, and environmental influences.

Future research should explore longitudinal trajectories of executive function and mathematics achievement, examining how early cognitive capacities predict later academic outcomes. Tracking development over time can identify critical periods for intervention and highlight the long-term benefits of strengthening executive functions. Experimental studies investigating targeted executive function training interventions in classroom settings can determine causal effects on early numeracy performance. Incorporating digital tools, gamified exercises, and scaffolded problem-solving tasks may provide practical methods for enhancing cognitive readiness while supporting mathematics learning. Cross-cultural research can further illuminate how different educational systems and instructional approaches influence the interplay between executive functions and early mathematics. Comparative studies across diverse socio-economic and cultural contexts may reveal universal and context-specific mechanisms, informing globally relevant educational strategies. Implementation-oriented research is recommended to translate findings into teacher training programs, curriculum development, and policy guidelines. Collaborative initiatives between cognitive psychologists, educators, and curriculum designers can ensure that early mathematics instruction integrates executive function development, promoting equitable and effective learning experiences.

CONCLUSION

The most significant finding of this study is that working memory, inhibitory control, and cognitive flexibility each contribute uniquely to early mathematics achievement, with working memory emerging as the strongest predictor of numeracy performance. Children with balanced executive function profiles demonstrated superior arithmetic, pattern recognition, and adaptive problem-solving abilities, highlighting the integrative role of these cognitive processes. This research emphasizes the interactive effects of executive functions rather than treating them as isolated skills, offering a more nuanced understanding of the cognitive mechanisms that underlie early numeracy. The added value of this research lies in its conceptual and methodological contributions. Conceptually, the study bridges cognitive psychology and early mathematics education by demonstrating how specific executive function components underpin numeracy development.

Methodologically, the combination of standardized assessments, multiple regression analysis, and observational case studies provides a comprehensive approach to examining cognitive predictors, offering a model for future interdisciplinary research in educational psychology and early childhood development. This dual contribution enhances both theoretical frameworks and practical implications for curriculum design and instructional strategies. Limitations of the study include a relatively small sample size and the cross-sectional research design, which restricts the ability to infer causal relationships. The sample was limited to children aged 5 to 7 in specific educational settings, potentially affecting generalizability across different populations and cultural contexts. Future research should adopt longitudinal designs, larger and more diverse samples, and experimental interventions to examine causal effects and developmental trajectories of executive functions on mathematics achievement. Investigating additional moderating variables, such as classroom environment, teaching practices, and socio-emotional factors, would further strengthen the understanding of cognitive influences on early numeracy.

AUTHOR CONTRIBUTIONS

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.
Author 2: Conceptualization; Data curation; In-vestigation.
Author 3: Data curation; Investigation.

CONFLICTS OF INTEREST

The authors declare no conflict of interest

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