Buletin Edukasi Indonesia (BEI)
DOI: 10.56741/bei.v3i03.757

E-ISSN 2962-1674
P-ISSN 2962-5742



Literature Review on Longitudinal Study of Improving Numerical Literacy at Elementary Education

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Abstract

Numerical literacy is a fundamental skill in early childhood education, influencing later academic performance and cognitive development. A growing body of research has identified several factors that contribute to the development of numeracy skills, including home learning environments, executive function, socio-emotional skills, and socio-economic status. Understanding these factors is crucial for developing effective interventions that support children's numeracy growth, especially in elementary education. This literature review synthesizes findings from longitudinal studies published between 2010 and 2024, focusing on the impact of home numeracy environments, executive function, socio-emotional skills, and socio-economic factors on early numeracy development. A total of five studies, with sample sizes ranging from small cohorts to large national samples, were analyzed. These studies employed longitudinal designs, assessing children over multiple years to capture the development of numeracy skills from preschool through elementary education. The review highlights the critical role of home learning environments, parental education, and socio-emotional skills in shaping children's numeracy development. It also identifies bidirectional associations between cognitive and emotional skills, underscoring the need for integrated approaches to numeracy instruction. Socio-economic status was found to indirectly impact numeracy development, with home literacy and numeracy environments mediating this relationship. Long-term effects of early home-based learning on arithmetic fluency were also observed, emphasizing the importance of fostering supportive environments early in education. This review concludes that targeted interventions in home environments, as well as strategies that integrate cognitive and socio-emotional support, can significantly enhance numerical literacy outcomes in elementary education. Further research is needed to address gaps in understanding how these factors interact across diverse cultural and socio-economic contexts.

Keywords: *cognitive development, elementary education, executive function, home learning environment, longitudinal study, numerical literacy, socio-emotional skills.*

Introduction

Research indicates that numeracy literacy is crucial for elementary students' success and societal participation [1]-[3]. Schools can improve numeracy literacy through various strategies. The Kampus Mengajar program has shown positive results in enhancing students' numeracy skills, particularly in underdeveloped areas, by introducing innovative learning approaches [4]. Implementing problem-based and project-based learning methods can also be effective, although resource limitations may pose challenges [5]. Teacher training in numeracy literacy is essential for optimizing these efforts [5]-[7]. Schools should focus on contextual and problem-based concept teaching, while also considering projection-based learning [8]. Improving facilities, addressing learning motivation issues, and allocating specific funds for numeracy literacy programs can further support these initiatives [9]. Additionally,

enhancing library resources and creating public spaces for numeracy activities can contribute to a more comprehensive approach [7],[10].

Improving numerical literacy at the elementary education level is a critical foundation for students' long-term academic success and future problem-solving abilities. Early numeracy skills are directly linked to later academic achievements in mathematics and other STEM fields, which are essential in the modern, data-driven world. As a core competency, numerical literacy influences cognitive development, decision-making, and even socio-economic mobility. Understanding the factors that shape numeracy in early childhood—such as home environments, cognitive abilities, and socio-emotional skills—can provide valuable insights for developing effective interventions and educational policies. Ensuring that all children, regardless of their background, have equal opportunities to develop these skills is crucial for fostering a more equitable educational landscape.

Despite the growing body of research on early numeracy development, several gaps remain in our understanding. First, while studies have explored the roles of home learning environments, executive functions, and socio-emotional factors, more research is needed to examine how these elements interact in diverse cultural and socio-economic contexts. There is also a need for longitudinal studies that track numeracy development over a broader age range, from early childhood through elementary education, to understand long-term impacts. Additionally, research that integrates various developmental domains—such as cognitive, emotional, and environmental factors—into a holistic framework for improving numerical literacy remains limited. Addressing these gaps will allow educators and policymakers to design more comprehensive and effective strategies to support children's numerical literacy development across different settings and communities.

The objective of this literature review is to synthesize existing longitudinal research on the factors influencing numerical literacy development in elementary education. Specifically, this review aims to examine how home learning environments, executive function, social-emotional skills, and socio-economic factors impact early numeracy skills. By identifying key trends, relationships, and gaps in the current body of research, this review seeks to provide a comprehensive understanding of the developmental processes underlying numerical literacy. Additionally, the review aims to highlight effective interventions and strategies for improving numeracy outcomes, with a focus on the integration of cognitive, emotional, and environmental factors in educational practices. Ultimately, the goal is to inform future research and educational policies to support the long-term development of numerical literacy in diverse educational contexts.

Methods

This literature review focuses on synthesizing findings from longitudinal studies published between 2010 and 2024 that examine factors influencing numerical literacy in elementary education. The review specifically includes studies that explored the impact of home learning environments, executive function, socio-emotional skills, and socio-economic status on numeracy development. A systematic search was conducted using academic databases such as Scopus and Elicit AI to identify relevant studies. The selected articles were screened based on their title, abstract, and methodology to

E-ISSN 2962-1674
P-ISSN 2962-5742

ensure they met the inclusion criteria. A total of five studies were included in the final review, covering a range of research topics related to numeracy development, including home learning environments, executive function, and socio-economic influences.

The inclusion criteria for the study were as follows: articles published between 2010 and 2024, appearing in journals indexed in Scopus within quartiles Q1 to Q3. The study type was limited to longitudinal research, ensuring a focus on in-depth, time-based analyses. Additionally, eligible articles must contain the keywords "Numerical Literacy" and "Elementary Education" in the abstract, ensuring relevance to the core themes of the research. The search for relevant articles was conducted using Elicit AI to optimize the identification and selection process. See Fig. 1 for the filtering process in this study.

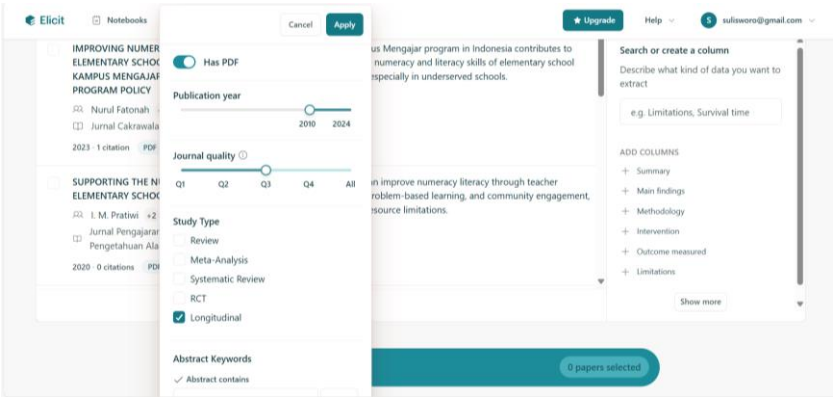


Fig. 1. The filtering process in this study using Elicit AI

Results

Based on the provided table, 6 articles meet the inclusion criteria for this literature review. These articles were published in journals indexed in Scopus Q1-Q3 and employ longitudinal designs to examine various factors influencing numerical literacy in elementary education. Table 1 presents the list of related journals and articles.

Table 1. The source identities

Paper	Abstract summary	Methodology	Outcome measured
Development of Numeracy and Literacy Skills in Early Childhood—A Longitudinal Study on the Roles of Home Environment and Familial Risk for Reading and Math Difficulties	Parental factors like reading/math difficulties and home numeracy/literacy environment predict children's numeracy and literacy skill development.	Longitudinal design following 265 Finnish children from age 2.5 to 6.5 years Individual assessments of children's numeracy skills (counting objects, number production, number sequence knowledge, number symbol knowledge, number naming) and literacy skills (vocabulary, print knowledge, letter knowledge) Parent-reported measures of parental education, reading difficulties (RD), math difficulties (MD), home numeracy environment (HNE), and home literacy environment (HLE)	The primary outcomes measured in this study are children's early literacy and numeracy skills, including counting objects, number production, number sequence knowledge, number symbol knowledge, number naming, vocabulary, print knowledge, and letter knowledge, assessed longitudinally from age 2.5 to 6.5.
The role of executive function and social-emotional skills in the development of literacy and numeracy during preschool: a cross-	The development of executive function and academic skills in literacy and numeracy are interrelated and complementary over time.	Longitudinal study design with 3-time points over 2 school years - Sample of 3,862 children with a mean age of 5.2 years at baseline Direct assessment of executive function, social-emotional, literacy, and numeracy skills	The primary outcomes measured in this study were children's executive function, social-emotional skills, literacy skills, and numeracy skills.

E-ISSN 2962-1674
P-ISSN 2962-5742

Paper	Abstract summary	Methodology	Outcome measured
lagged longitudinal study.		Cross-lagged longitudinal analysis to examine bidirectional associations between the skills	
Home Literacy and Numeracy Interact and Mediate the Relationship Between Socio-Economic Status and Early Linguistic and Numeracy Skills in Preschoolers	Home literacy and numeracy mediate the relationship between socioeconomic status and early linguistic and numeracy skills in preschoolers.	Participants: 310 Italian monolingual preschool children assessed at two time points (second and third year of preschool) Measures: Parents completed questionnaires on SES and home literacy/numeracy; children were assessed on language, non-symbolic numeracy, early literacy, and symbolic numeracy skills Procedure: Children attended a public preschool program as part of a larger project, and were assessed individually or in small groups	The primary outcomes measured in this study were early language skills (vocabulary and morpho-syntactic comprehension), early literacy skills (early writing, letter knowledge, and phonological awareness), non-symbolic numeracy skills (quantity comparison and seriation), and symbolic numeracy skills (number recognition and biunivocal correspondence).
Improving numeracy through values affirmation enhances decision and STEM outcomes	Values affirmation can improve numeracy and enhance decision-making and STEM outcomes in undergraduate students.	The study used a randomized controlled trial design with pre- and post-intervention measures. Participants were undergraduates recruited from a required psychology statistics course and were randomly assigned to either a values-affirmation or control condition. Participants completed various measures at the beginning and end of the term, including subjective and objective numeracy, decision-related outcomes, and STEM-related outcomes. Participants' transcripts were also obtained 1-2 years later to assess math-intensive course enrollment.	Objective numeracy, subjective numeracy, financial literacy, financial outcomes, and health-related behaviors
An explanatory model of emotional-cognitive variables in school mathematics performance: a longitudinal study in primary school	Early mathematical competencies and a positive predisposition toward mathematics predict long-term performance in school mathematics.	634 primary school Chilean students aged 8-11 years old, enrolled in grades 3-6, selected using a non-probabilistic accidental sampling method - Assessment instruments used: 1) Early Numeracy Test (ENT) to assess early numeric knowledge and learning difficulties 2) Test of Logical Intelligence (TILE) to assess logical-relational competencies 3) Predisposition toward Mathematics (EPMAT) scale to assess attitudes and predisposition toward mathematics Academic performance measured as grade point average in mathematics over 4 years Longitudinal design to assess the predictive power of the variables on academic performance	The primary outcome measured in this study was the grade point average (GPA) obtained by the students in mathematics over 4 years.
Longitudinal Effects of the Home Learning Environment and Parental Difficulties on Reading and Math Development Across Grades 1–9	Parental reading and math difficulties, home literacy/numeracy environment, and maternal education predict children's reading and math development through elementary school.	Longitudinal study design following 2,525 Finnish children from kindergarten to grade 9 Standardized tests are administered to assess children's reading fluency, reading comprehension, and arithmetic fluency in grades 1, 2, 3, 4, 7, and 9 Parents reported their own reading and mathematical difficulties as well as home learning activities (shared reading, literacy teaching, numeracy teaching) when children were in kindergarten	1. Reading fluency, measured as the mean of three standardized reading fluency tests 2. Reading comprehension, measured using a standardized reading comprehension test 3. Arithmetic fluency, measured using a standardized arithmetic fluency test
Building school-wide capacity for improvement: The role	The paper does not directly address improving numeracy	Longitudinal data collection from 1,010 teachers in 32 Dutch elementary schools Mixed-model analysis of the data	School-wide capacity for improvement, as measured by

E-ISSN 2962-1674
P-ISSN 2962-5742

Paper	Abstract summary	Methodology	Outcome measured
of leadership, school organizational conditions, and teacher factors	literacy in elementary education but suggests that building school-wide capacity for continuous improvement, through leadership, organizational conditions, and teacher factors, is important.	Measurement of school-wide capacity for improvement, including leadership practices, school organizational conditions, teacher motivation, and teacher learning	leadership practices, school organizational conditions, teacher motivation, and teacher learning
Numeracy, Health Literacy, Cognition, and 30-Day Readmissions among Patients with Heart Failure	This paper is not relevant to the query about improving numeracy literacy in elementary education, as it examines the relationship between numeracy, health literacy, cognition, and 30-day readmissions among patients with heart failure.	The study used a prospective observational design to examine the relationship between numeracy, health literacy, cognition, and 30-day readmissions among patients hospitalized for acute decompensated heart failure. Participants completed a baseline interview during hospitalization and were followed up at 30 days to assess all-cause readmission, which was determined through patient interviews, electronic medical record review, and review of outside hospital records. Numeracy was measured using the Subjective Numeracy Scale, health literacy was assessed with the Brief Health Literacy Screen and Test of Functional Health Literacy in Adults, and cognition was evaluated with the Short Portable Mental Status Questionnaire.	30-day readmission to any acute care hospital

Discussion

From the provided table, several longitudinal studies examine factors influencing numerical literacy in elementary education.

A. Development of Numeracy and Literacy Skills in Early Childhood

The study by Salminen [11] highlights the critical role of the home numeracy environment (HNE) and parental factors in shaping children's early numerical literacy. Specifically, it investigates how variables such as parental education, parental reading and math difficulties, and home literacy and numeracy practices influence the development of foundational numeracy and literacy skills. The longitudinal study followed 265 Finnish children from ages 2.5 to 6.5 years, conducting individual assessments on numeracy skills, including counting objects, number production, sequence knowledge, number symbol recognition, and number naming. These skills represent essential building blocks for later mathematical competence.

In addition to child-focused measures, parents reported their education levels, and any history of reading or math difficulties, as well as the quality of the literacy and numeracy environment they provided at home [11]. The findings demonstrate that children from supportive home environments with enriched numeracy practices performed better in numeracy assessments over time. Conversely, familial risks such as parental reading or math difficulties were associated with slower development in these areas. These results emphasize the importance of early interventions aimed at fostering numeracy-rich home environments to mitigate potential risks and improve children's mathematical readiness for school.

By tracking developmental trajectories over four years, this study provides strong evidence for the enduring impact of early home-based learning environments on numerical literacy. It suggests that

equipping families with resources and strategies to promote numeracy-related activities at home could play a transformative role in children's mathematical development [11],[12].

B. The Role of Executive Function and Social-Emotional Skills

The study [13] explores the interplay between executive functions, social-emotional skills, and numerical literacy in preschool-aged children. Conducted over three-time points across two academic years, this longitudinal research included a large sample of 3,862 children with a mean age of 5.2 years at baseline. The methodology employed direct assessments of executive function, social-emotional competencies, and numeracy skills, utilizing cross-lagged longitudinal analysis to examine bidirectional associations among these developmental domains.

The findings reveal that executive functions, such as working memory and cognitive flexibility, and social-emotional skills, including self-regulation and emotional awareness, are closely linked to the development of numerical literacy. Notably, these associations are reciprocal, indicating that improvements in one domain can positively influence others [14]. This insight underscores the need to design interventions that integrate cognitive and emotional development strategies to enhance numeracy outcomes in young learners. For example, fostering self-regulation and problem-solving skills could indirectly boost mathematical competence by creating a more robust foundation for learning [15].

The study emphasizes the value of a holistic approach to early childhood education, addressing broader developmental areas beyond direct numeracy instruction [13]. It suggests that by targeting executive function and social-emotional skills, educators and policymakers can create comprehensive frameworks that support overall academic success, including numeracy [13],[15].

C. Home Literacy and Numeracy Interaction

The study [16] investigates the indirect influence of socioeconomic status (SES) on early numeracy development through home literacy and numeracy environments. Conducted longitudinally with 310 Italian monolingual preschool children, the research assesses the interplay between SES, home environments, and early skills. Parents completed questionnaires detailing SES and home practices, while children underwent assessments of language, non-symbolic numeracy, early literacy, and symbolic numeracy skills at two-time points during preschool.

The findings emphasize the critical roles of symbolic numeracy skills, such as number recognition and biunivocal correspondence, and non-symbolic numeracy skills, such as seriation and quantity comparison, in laying the foundation for numerical literacy in elementary education [16],[17]. The study demonstrates that a stimulating home numeracy environment can partially mediate SES-related disparities, fostering early mathematical competencies despite socioeconomic challenges. For example, children from lower SES backgrounds with enriched numeracy practices at home exhibited improved numeracy outcomes, highlighting the potential of targeted interventions.

By illustrating the interconnectedness of SES, home environments, and early numeracy, this research provides valuable insights for designing policies and programs aimed at reducing educational inequities. Encouraging parents to engage in numeracy-focused activities with their children could bridge gaps in early mathematical development and enhance readiness for elementary education [16].

E-ISSN 2962-1674
DOI: 10.56741/bei.v3i03.757
P-ISSN 2962-5742

D. Longitudinal Effects of the Home Learning Environment

The study [18] provides a detailed exploration of how home learning environments and parental factors influence children's numeracy and literacy development over an extended period. Tracking 2,525 Finnish children from kindergarten through grade 9, the research employed standardized assessments of reading fluency, reading comprehension, and arithmetic fluency across multiple time points in grades 1, 2, 3, 4, 7, and 9. Parents reported their difficulties with reading and mathematics, as well as home learning activities, such as shared reading, literacy teaching, and numeracy teaching.

The findings reveal that parental education, coupled with an enriched home learning environment, significantly predicts arithmetic fluency over time [18]. Early exposure to structured numeracy activities, such as counting and arithmetic exercises at home, has a lasting impact on numerical literacy [19], demonstrating the prolonged influence of early learning experiences on later academic performance [20]. For instance, children who engaged in frequent home-based numeracy activities in kindergarten displayed stronger arithmetic fluency in subsequent grades.

This study underscores the critical importance of fostering supportive home learning environments during the elementary years to promote sustained academic success [18]. The results advocate for early interventions aimed at equipping parents with tools and strategies to create enriching educational experiences at home, thereby mitigating potential disadvantages stemming from parental difficulties in literacy or numeracy [18],[20].

The findings from these longitudinal studies collectively highlight the profound and lasting impact of early developmental factors—particularly home learning environments, parental involvement, and the integration of cognitive and emotional skills—on children's numerical literacy in elementary education. These studies emphasize that improving numerical literacy in elementary education requires a holistic approach that goes beyond the classroom. Effective strategies should involve enhancing the home learning environment, integrating emotional and cognitive skill development, and providing targeted interventions for children from diverse backgrounds. Additionally, supporting parents in fostering numeracy at home, particularly in low SES communities, is critical to ensuring equitable access to educational opportunities. Ultimately, these findings suggest that early and sustained efforts to improve numerical literacy, through both cognitive and socio-environmental pathways, can have a profound impact on children's academic trajectories, preparing them for success in later stages of education.

Conclusion

These longitudinal studies emphasize the crucial role of early developmental factors, such as home numeracy and literacy environments, executive function, and social-emotional skills, in shaping children's numerical literacy. Interventions targeting both cognitive and emotional development, alongside fostering supportive home learning environments, are essential for improving numeracy outcomes in elementary education. Additionally, addressing socioeconomic disparities through targeted home-based activities can significantly enhance early numeracy skills. These insights provide valuable

directions for future educational practices and policy, highlighting the importance of early and continuous support to ensure long-term numeracy development in children.

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