WHAT COUNTS AS FOUNDATIONAL NUMERACY? A POST-COVID SCOPING REVIEW OF EARLY NUMBER LEARNING IN MARGINALISED GLOBAL SOUTH CONTEXTS

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Early number learning strongly predicts later mathematics achievement, yet there is limited clarity on how foundational numeracy is currently conceptualised and measured in Global South research. This scoping review maps 35 peer-reviewed academic studies on early number learning published between 2022 and 2025 in the post-COVID period. Drawing on Whitacre et al.'s (2020) framework, the analysis shows that most studies define early numeracy through symbolic performance on basic number tasks, typically assessed using short, standardised early-grade numeracy tools. Approximate number sense and mature whole number reasoning are rarely central constructs. This dominance of symbolic attainment indicators produces strong evidence for system monitoring, but offers limited insight into conceptual understanding. The findings suggest the need for a broader conception of foundational numeracy that integrates fluency with understanding.

INTRODUCTION

The importance of establishing strong foundations for learning in the early years is now widely recognised. Early differences in literacy and numeracy skills tend to widen over time, and unequal outcomes are often visible within the first years of schooling, particularly in Global South contexts (Kaffenberger & Pritchett, 2020). In this paper, we use the term Global South to refer to countries with shared histories of colonisation and relatively low national incomes, mainly located in Africa and parts of Southern Asia and Latin America. In many of these systems, a majority of children do not reach expected mathematical outcomes, prompting Venkat and Adler (2025) to describe such contexts as settings of "majority marginalisation" in mathematics learning.

Across these settings, foundational literacy and numeracy (FLN) has moved to the centre of policy attention. FLN is commonly defined as the basic learning outcomes expected by the end of Grade 3 under Sustainable Development Goal 4.1.1a (UNICEF, 2022). However, what counts as foundational numeracy remains difficult to pin down. Ma (2013) describes the mathematics underlying whole number arithmetic as foundational, while acknowledging that 'number sense' is the goal of this learning, which is defined in various ways. These differences make it difficult to obtain a clear

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picture of what is meant by "foundational numeracy," and how it is being measured and supported across different contexts.

At the same time, research in mathematics education and cognitive science describes early numeracy as multidimensional, including procedural skills and relational understanding (Gersten & Chard, 1999; Siegler & Lortie-Forgues, 2014). Yet it is not always clear how these theoretical ideas align with how numeracy is measured in research and monitoring, particularly in Global South contexts where large-scale assessments dominate. This paper examines how early number learning is conceptualised and measured in recent academic research on the Global South. Our review is guided by two questions: (1) What research purposes dominate recent academic studies of early number learning in Global South contexts? (2) How do the design features of commonly used assessment instruments shape the kinds of evidence produced, and which aspects of number sense are foregrounded?

THEORETICAL BACKGROUND

"Number sense" is widely cited as a core goal of early mathematics education, but the term has been defined in multiple ways (Whitacre et al., 2020). Whitacre et al. (2020) argued that the term is used to describe three distinct constructs, which emerge from different research traditions and theoretical commitments. These are:

1. **Approximate number sense (ANS):** Rooted in cognitive science, ANS refers to the ability to perceive and compare quantities non-symbolically (e.g., identifying which set is larger). It is typically measured through rapid comparison tasks, where performance varies based on the ratio between the two quantities, with large ratios (it is easier to distinguish which quantity is larger when the ratio is larger). ANS does not require knowledge of number words or symbols and is studied across the lifespan.

2. **Early symbolic number sense (ENS):** This includes recognising and writing numerals, counting, comparing symbolic magnitudes, identifying number patterns, estimating, and carrying out simple arithmetic operations. A variety of assessments focus on these elements, ranging from broad tools to very task-specific measures.

3. **Mature number sense (MNS):** This category refers to later-developing relational understandings. It includes place-value structure, multi-digit whole-number computation, rational-number work, flexible mental strategies, and the evaluation of the reasonableness of answers. Here, emphasis lies on strategy, structure, and flexibility, rather than correctness alone.

There is overlap between categories, but also key distinctions. ENS relies on symbolic knowledge, whereas ANS does not, and MNS foregrounds strategic and relational thinking, which is harder to assess using short, closed-response tests that score only correctness rather than the strategies used to produce answers (Whitacre et al., 2020). Whitacre et al.'s framework is helpful in low-income contexts, where available data on early number learning are often limited (Devarajan, 2013). It clarifies which aspects of

number sense are measured in any given study and which remain invisible. This matters in contexts of majority marginalisation, where many learners do not reach grade-level outcomes (Venkat & Adler, 2025). In this review, we use the framework to classify studies and examine how assessment instruments shape what counts as number sense.

METHODOLOGY

We conducted a scoping review of peer-reviewed empirical studies and systematic reviews on early numeracy in early-years or early-primary settings in Global South contexts, published in English between 2022 and 2025. Searches combined terms such as early numeracy, foundational learning, early mathematics, number sense, low- and middle-income countries, and the Global South across the Scopus, Web of Science, ERIC, PsycINFO, and Academic Search Complete databases. Studies were included if they reported empirical findings or evidence syntheses on early number learning in low- or lower-middle-income settings; work focused solely on high-income or upper-middle-income systems with strong assessment capacity, advanced mathematics topics or literacy-only outcomes was excluded. Grey-literature monitoring (e.g., NGO and national assessment reports) was conducted in the broader project but is not analysed here and will be reported separately.

For the 35 included studies, we extracted structured information on country, sample, design, assessment instruments and key findings. A subset of studies was double-coded independently, with discrepancies resolved through discussion. Each study was assigned a primary research purpose (e.g., intervention evaluation, predictive/correlational, pedagogy/conceptual inquiry, monitoring, review) and a dominant numeracy construct (approximate, early symbolic, mature number sense) based on Whitacre et al.'s (2020) framework.

RESULTS

Purposes and basic characteristics of the included studies

The final corpus comprised 35 studies, most conducted in Sub-Saharan Africa and South Asia, with samples ranging from small classroom cases to large national surveys. Each study was first coded for its primary research purpose, based on the main stated aim. Table 1 summarises these purposes. As Table 1 shows, foundational numeracy features are found within different kinds of studies. Measurement appears most often in programme or intervention evaluations (31%) and predictive/correlational analyses (26%), followed by pedagogy/conceptual inquiry (20%) and population monitoring/descriptive work (17%), with reviews relatively rare (6%).

Table 1: Primary research purpose of the 35 included studies.

Primary research purpose	**Description**	**Number of studies n (%)**
Programme/intervention evaluation	Estimate the effects of programmes, interventions, or instructional models on early numeracy outcomes	11 (31%)
Predictive /correlational	Examines associations between numeracy outcomes and child, home, school or contextual factors; or examines how early numeracy predicts later outcomes	9 (26%)
Pedagogy / conceptual inquiry	Examines classroom practice, strategy use, or conceptual development in number learning	7 (20%)
Population monitoring / descriptive	Reports population-level early numeracy outcomes without modelling predictors or effects	6 (17%)
Reviews	Evidence synthesis with no new primary data	2 (6%)

Assessment designs and numeracy instruments

A second layer of coding examined how early number learning was assessed in the 35 studies. Table 2 summarises the main assessment instruments.

Table 2: Core numeracy assessment instruments represented in the review (N = 35).

Instrument	**Developer / Organisation**	**Format / Setting / Typical age range**	**Core numeracy domains assessed**
EGMA (Early Grade Mathematics Assessment)	RTI International / USAID	1:1 oral / EDU / ~6-9 years	number ID; counting; comparison; addition/subtraction (+/-)
IDELA (International Development and	Save the Children	1:1 oral / EDU / ~4-7 years	counting; number ID; quantity comparison; non-symbolic quantities

Early Learning Assessment)			
ELOM (Early Learning Outcomes Measure)	South African research consortium	1:1 oral / EDU/HH / ~4-5 years	counting; comparison; patterning; early quantitative reasoning
ASER / Uwezo foundational numeracy tests	ASER Centre (India) / PAL Network	1:1 oral / HH / ~5-14 years	number ID; counting; basic arithmetic (+/-)
MICS-ECDI (Early Childhood Development Index)	UNICEF	Caregiver report / HH / 3-4 years	Caregiver-reported number recognition and counting
Teaching at the Right Level (TaRL) numeracy assessments	Pratham / TaRL Africa	1:1 oral / EDU / ~6-12 years	number ID; counting; basic operations (instructional grouping)
MARKO-D / MARKO-D SA diagnostic interviews	University-based researchers (Germany; South Africa adaptation)	1:1 oral / EDU / ~4-8 years	cardinality; part-whole relations; relational reasoning
Programme- or study-developed tools	University or NGO research teams	varies / EDU or HH / age- or grade-specific	foundational numeracy domains (varies by study)

Note: *Domains listed are representative of the primary numeracy constructs assessed and reported in the reviewed studies, rather than exhaustive inventories of all tasks included in each instrument.* ***EDU*** *= educational setting;* ***HH*** *= household setting.*

Across the 35 studies reviewed, most numeracy data were generated through short, scripted assessments administered one-to-one with children in educational or household settings (e.g., EGMA, IDELA, ELOM, ASER/Uwezo), or through caregiver-reported MICS-ECDI items. As shown in Table 2, these instruments predominantly assess early symbolic number sense, most commonly number identification, counting, and basic operations. A smaller subset of studies relied on locally developed, curriculum-aligned achievement tests within programme

evaluations, which similarly emphasised foundational arithmetic performance rather than conceptual structure. In contrast, only three studies employed theory-driven diagnostic interviews (MARKO-D/MARKO-D SA) designed to probe conceptual number knowledge, including part-whole relations and relational reasoning.

Importantly, while several instruments are administered one-to-one, this does not in itself imply conceptual assessment. Studies using MARKO-D were explicitly grounded in a developmental model of number concepts (e.g., Bezuidenhout, 2022), whereas the developmental assumptions underpinning EGMA, IDELA, and ELOM tended to be implicit in the reviewed studies (e.g., Pisani et al., 2022). Taken together, the reviewed studies show a strong empirical emphasis on attainment: whether children can recognise numerals, count correctly, or solve simple operations, with far less attention to the conceptual structure and strategy use underlying mathematical thinking.

Distribution of number-sense constructs

Using Whitacre et al.'s (2020) framework, each study was coded according to the dominant number-sense construct reflected. These categories reflect how numeracy instruments were used and interpreted within the reviewed studies, rather than fixed or exhaustive properties of the instruments themselves.

Table 3: Distribution of number-sense constructs across included studies (N = 35)

Construct	n	Percentage
Approximate number sense (ANS)	0	0%
Early symbolic number sense (ENS)	28	80%
Mature whole-number sense (MNS)	7	20%

As Table 3 indicates, no study directly assessed ANS. Twenty-eight studies (80%) assessed ENS, typically through short items on numeral recognition, counting, magnitude comparison or simple operations. Only seven studies (20%) examined aspects of MNS (e.g., part-whole reasoning, relational understanding, flexible strategy use), usually via diagnostic interviews. Thus, conceptual aspects of number sense appeared in only a small minority of studies.

DISCUSSION AND IMPLICATIONS

This review shows that, across recent Global South research, early numeracy is predominantly operationalised as performance on brief symbolic tasks, such as numeral recognition, counting, and basic operations. As a result, although number sense is widely theorised as a multidimensional construct encompassing both symbolic competence and relational understanding, the published evidence base reflects a much narrower portion of that construct. Importantly, this pattern does not map simply onto

test setting or administration mode: several widely used early-grade assessments are administered one-to-one with children, yet still focus primarily on procedural accuracy in symbolic tasks. The key distinction is therefore not assessment format, but whether instruments are designed to elicit conceptual understanding and strategy use.

This pattern aligns with the well-established distinction between procedural and conceptual knowledge in mathematics learning (Rittle-Johnson & Schneider, 2015). In large-scale monitoring contexts, assessments often tend to emphasise procedural accuracy because such outcomes are easier to standardise and scale for policy use in FLN systems. However, conceptual and procedural knowledge are mutually reinforcing rather than sequential (Rittle-Johnson & Schneider, 2015; Schneider et al., 2017). When monitoring relies predominantly on brief symbolic tasks, the conceptual dimension becomes less visible, despite theory positioning it as central to learning (Siegler & Lortie-Forgues, 2015; Whitacre et al., 2020). The issue is not that procedural assessments are inadequate: they are essential for tracking access and attainment, but when used in isolation, they risk under-representing conceptual understanding and becoming the de facto definition of foundational numeracy (Siegler & Lortie-Forgues, 2015; Whitacre et al., 2020). A pragmatic response is not to abandon system-level testing, but to complement it with forms of conceptual sampling that remain viable in low-resource systems. Even limited, strategically sampled conceptual data would broaden what becomes visible in large-scale FLN monitoring and help align research more closely with multidimensional theories of number sense.

This review is bounded in scope: it focuses on journal-published work from 2022-2025 and excludes the grey-literature monitoring work that dominates much Global South assessment activity. Some relevant studies will therefore be missing, and the patterns discussed here should be read as recent tendencies rather than an exhaustive map. Nonetheless, the consistency with which symbolic performance dominates across diverse settings suggests that the field currently foregrounds attainment more strongly than understanding. Recognising this imbalance opens space for assessment designs that reflect both.

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***Note**: *Full list of 35 studies included in the review is available from the authors on request.*