Zizi Afrique Foundation

REPUBLIC OF KENYA

Centre for Mathematics, Science and Technology Education in Africa (CEMASTEA)

FOUNDATIONAL NUMERACY IN KENYA: Status, Opportunities and Challenges

Summary Findings on the Most Common Errors in Early Grade Numeracy Classrooms: Insights for Practice.

Produced by:

Center for Mathematics, Science and Technology Education in Africa (CEMASTEA) and Zizi Afrique Foundation.

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Acknowledgement

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The success of this initiative is a testament to the dedication, openness, and collaborative spirit of all our partners and stakeholders. We are truly grateful for their contributions.

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About Centre for Mathematics, Science and Technology Education in Africa (CEMASTEA).

The Centre for Mathematics, Science and Technology Education in Africa (CEMASTEA) is a Semi-Autonomous Government Agency (SAGA), under the Ministry of Education, Science and Technology (State Department of Early Learning and Basic Education), dedicated to enhancing the quality of Mathematics and Science education through In-Service Education and Training (INSET) for teachers in Kenya and beyond. Established in 2003, CEMASTEA has grown into a regional hub for Teacher Capacity Development, offering specialized training programs for primary and secondary school educators and customized courses for African countries in Science, Technology, Engineering, and Mathematics (STEM). In partnership with key education stakeholders like the Ministry of Education, the Teacher Service Commission, and international partners (e.g., The World Bank), CEMASTEA conducts research, supports the integration of ICT in education, and promotes STEM education. As the secretariat for Strengthening Mathematics and Science Education in Africa (SMASE-Africa), CEMASTEA plays a vital role in strengthening Mathematics and Science education across the continent, fostering innovation, and equipping educators with modern pedagogical skills.

About Zizi Afrique Foundation (ZAF)

Zizi Afrique Foundation (ZAF) is a dynamic, not-for-profit organization dedicated to transforming learning outcomes for children and youth furthest behind. Operating at the intersection of evidence, policy, and practice, ZAF leverages research to drive systemic improvements in public education. Formally incorporated in 2018, ZAF envisions a future where every child builds a strong foundation in learning and every youth transitions smoothly into life and the world of work. Committed to systems change, ZAF collaborates closely with government institutions to strengthen foundational learning outcomes through research and innovation. To unearth pedagogical barriers to numeracy outcomes, ZAF has partnered with CEMASTEA to gather evidence on the most common errors in numeracy in early-grade classrooms and the implications these have for education leaders, teachers, and stakeholders.

Trends in Numeracy Outcomes

Background and context

A strong foundation in numeracy during primary school (ages 6–11) is crucial for lifelong learning and economic participation. Globally, however, a significant challenge persists: UNESCO (2021) reports that approximately 60% of children lack basic numeracy skills by the end of primary school, with low- and middle-income countries (LMICs) disproportionately affected. While boys and girls often demonstrate similar numeracy abilities in early childhood, girls frequently match or even surpass boys' skills, particularly in the early grades. However, as learners move to middle-level grades and senior schools, gender gaps begin to emerge and even widen with boys performing better in numeracy than girls. This disproportionate performance contributes to more boys than girls qualifying for STEM courses. For instance, in sub-Saharan Africa, girls in some countries outperform boys in numeracy at about 6–11 years, though societal barriers like early marriage and higher dropout rates can impede their continued educational progress (World Bank, 2022).

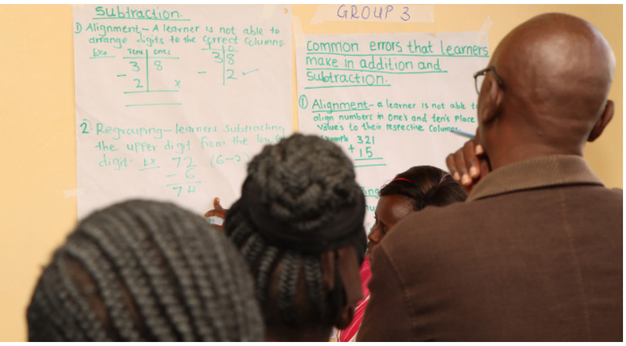
Research by Uwezo (2021) indicates that girls in Kenya and Uganda (East Africa) perform as well as, or slightly better than, boys in basic numeracy in Grades 2 and 3. Similar trends are observed in Southern Africa, with girls in Malawi and South Africa demonstrating comparable or superior early-grade numeracy skills (SACMEQ, 2017; UNICEF, 2020). Despite this favourable start, there tends to be a disparity at the highest levels of achievement and representation in fields like STEM, where boys may be more represented (NAEP, 2021). This pattern of girls' strong early numeracy is also seen in South Asia, where girls in India and Pakistan often perform on par with boys in early grades, although cultural norms and limited access to education can create disparities later (ASER, 2022; World Bank, 2021).

Addressing disparities that arise as boys and girls move to senior schools requires focused interventions to support girls' education and ensure equitable learning opportunities for all children, while also acknowledging and addressing the factors that contribute to disparities at the highest levels of achievement even in more equitable contexts.

Error Analysis in Education: A Reflective Practice for Improving Learning Outcomes.

What is Error Analysis?

Error analysis is a systematic approach to identifying, diagnosing, classifying, and addressing mistakes that learners make in the process of acquiring knowledge and skills. It is widely used in education to gain insights into learners' thought processes, misconceptions, and learning difficulties. The approach helps educators develop targeted interventions to enhance comprehension and mastery of subject matter.



Error analysis embodies reflective practice by encouraging teachers and learners to critically examine mistakes, their causes, and corrective measures. Reflective teaching involves continuous assessment and adaptation based on learners' responses to instruction. When teachers analyze errors, they reflect on their instructional strategies and assess whether they need to adjust content delivery, provide additional support, or introduce new pedagogical methods (Brookfield, 2017). On the other hand, students engage in self-reflection, developing metacognitive skills that enable them to identify and rectify their mistakes, fostering deeper learning (Schön, 1983). Such reflective practices enhance the acquisition of high-order skills in numeracy.

Why Error Analysis in Numeracy Instruction

Numeracy education benefits significantly from error analysis as mathematical understanding often builds on previous knowledge. The importance of error analysis in numeracy includes, but is not limited to:

1. **Detecting systematic errors:** Mathematics errors often follow patterns, and analyzing them helps identify misconceptions in numerical operations, place value, fractions, and problem-solving approaches (Kilpatrick et al., 2001).
2. **Improving computational fluency:** Recognizing the nature of computational errors (e.g., careless mistakes vs. conceptual errors) helps refine teaching methods (Hiebert & Grouws, 2007).
3. **Enhancing formative assessment:** Teachers can design lessons that address common errors before they become ingrained habits (Black & Wiliam, 1998).

In early numeracy learning, children often struggle with conceptual understanding, procedural fluency, and application of mathematical operations. Through error analysis, teachers can distinguish between conceptual errors (misunderstandings of mathematical principles) and procedural errors (mistakes in executing calculations). This reflective approach allows teachers to tailor interventions such as targeted remediation and differentiated instruction, fostering deeper comprehension and problem-solving skills among learners.

The Value Addition of Error Analysis

Incorporating error analysis into teaching practice adds value in the following ways:

1. **Promotes evidence-based instruction:** Data from error analysis informs instructional strategies that are tailored to specific learning needs.
2. **Improves teacher-learner interaction:** Teachers engage learners in meaningful discussions about their thought processes, improving communication and understanding.
3. **Fosters independent learning:** Students develop self-correction skills, enhancing their autonomy in the learning process (Zimmerman, 2002).
4. **Leads to better assessment and intervention:** Teachers can proactively design interventions that support struggling learners before errors become persistent issues.

To maximize its impact, error analysis should be integrated into professional development programs for early-grade teachers, equipping them with strategies to analyze learner responses systematically. By embedding reflective practice into daily instruction, educators can enhance numeracy outcomes and ensure foundational mathematical skills are effectively developed.

Moreover, error analysis encourages a positive learning environment where mistakes are viewed as learning opportunities rather than failures. When learners engage in self-correction and peer discussions on errors, they develop critical thinking and metacognitive skills essential for lifelong learning. This practice aligns with evidence-based teaching methodologies that emphasize formative assessment and continuous improvement.

Application of Error Analysis to Enhance Reflective Practice in Numeracy Instruction for Early Grade Learners

Error Analysis in Bungoma County

In 2024, CEMASTEA and Zizi Afrique Foundation in collaboration with Bungoma West Sub-County set to undertake a study to establish the most common errors learners make in numeracy. The learner scripts were reviewed to derive the errors, determine the misconceptions, and explore the implications of the findings for teachers in their classroom practice. Besides assessing learners' scripts, the assessment team conducted focus group discussions with headteachers and Grades 2 and 3 teachers, numeracy classroom observations, and interviews with teachers to establish perceptions regarding numeracy performance.

Data Collection Process

The data collection involved a mixed-method approach to gather detailed insights into teaching practices, classroom environments, and learner outcomes. Below is a summary of the scope of data collection:

Data collection tools	Sample Size
• Classroom lesson observation tool • Numeracy assessment (6 items, 3 each in addition and subtraction) • Learner survey tool • Teacher survey tool	• 5 schools • 405 learners (219 girls; 186 boys) • Focus grades: grade 2 and 3 • 12 early grade teachers

Common Errors in Numeracy and how they Manifest

1. Factual errors: These are errors due to a lack of information. The common errors are listed below:

i. Lack of understanding of basic number facts.
ii. Misunderstanding of signs.
iii. Misidentifying digits/failure to accurately recognize digits/numerals.
iv. Errors while counting (skipping digits during counting)
v. Lack of understanding mathematical terms
vi. Lack of knowledge in mathematical formulas

2. Procedural errors: These are errors due to the incorrect performance of steps in a mathematical process. The common errors include:

i. Forgetting (missing/skipped) to regroup
ii. Regrouping across a zero
iii. Performing incorrect operation
iv. Not aligning decimal points when adding or subtracting
v. Not placing decimals in the appropriate place when multiplying or dividing.

3. Conceptual errors: These are errors due to misconceptions or a faulty understanding of the underlying principles and ideas connected to the mathematical problem. The common errors include:

i. Misunderstanding of place value
ii. Overgeneralization (i.e., bigger number cannot be subtracted from smaller numbers (e.g., 21-19), mistaking all numeracy tasks as either addition or subtraction, subtracting greater numbers from less numbers (e.g., 21-19, the learner takes 9-1).

Numeracy Assessment Findings

Key Finding 1: Factual Errors were the Most Prevalent across the Grades.

Overall, of the **1,752** error occurrences, **1,474 (84%)** entries were factual errors, indicating that most learners lacked the basics of numeracy (that is, numbers and operations) specifically, they had limited understanding of basic number facts **(955)**, were confusing the basic signs **(175)**, had counting errors **(333)**, and failed to recognize number symbols **(11)** ***(see figure 1).***

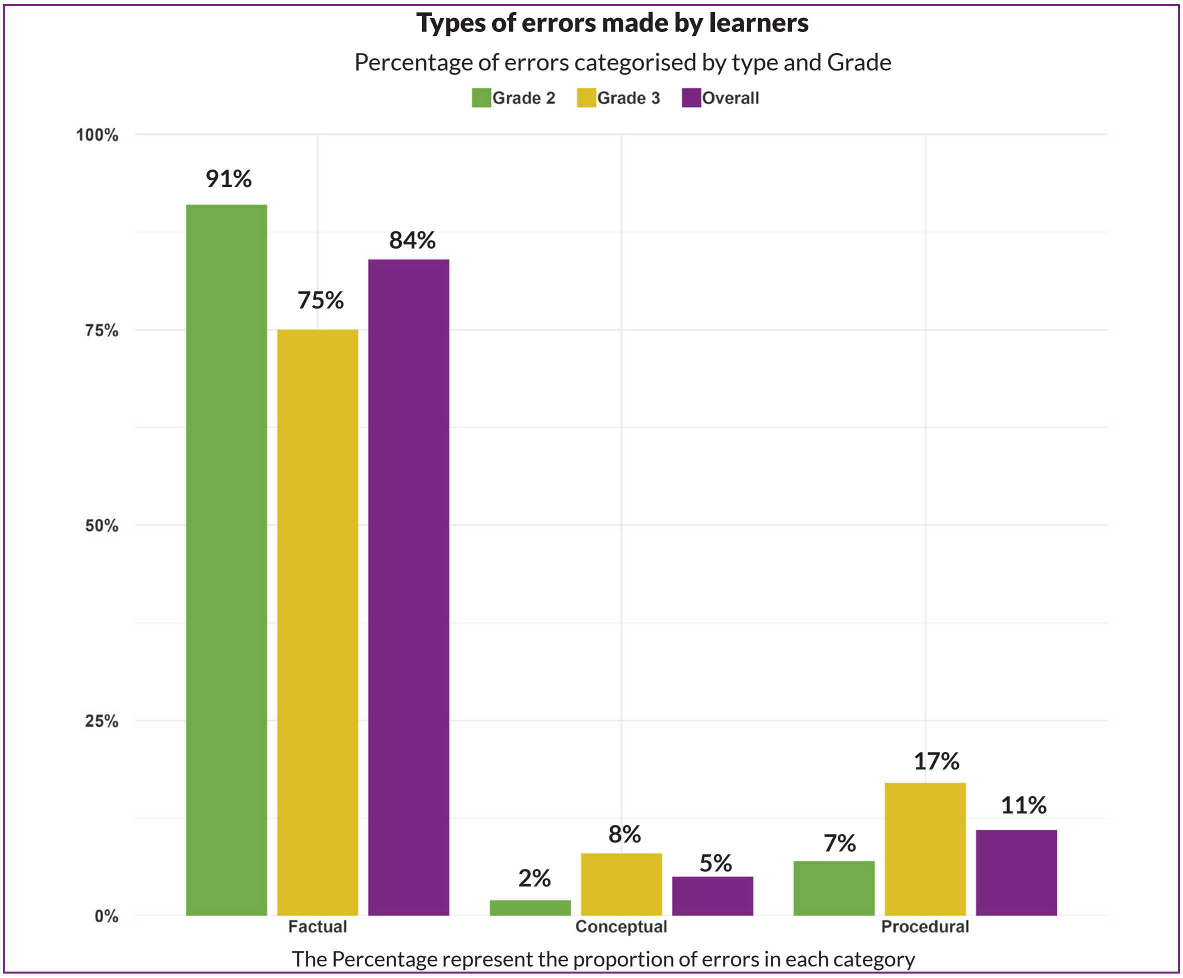
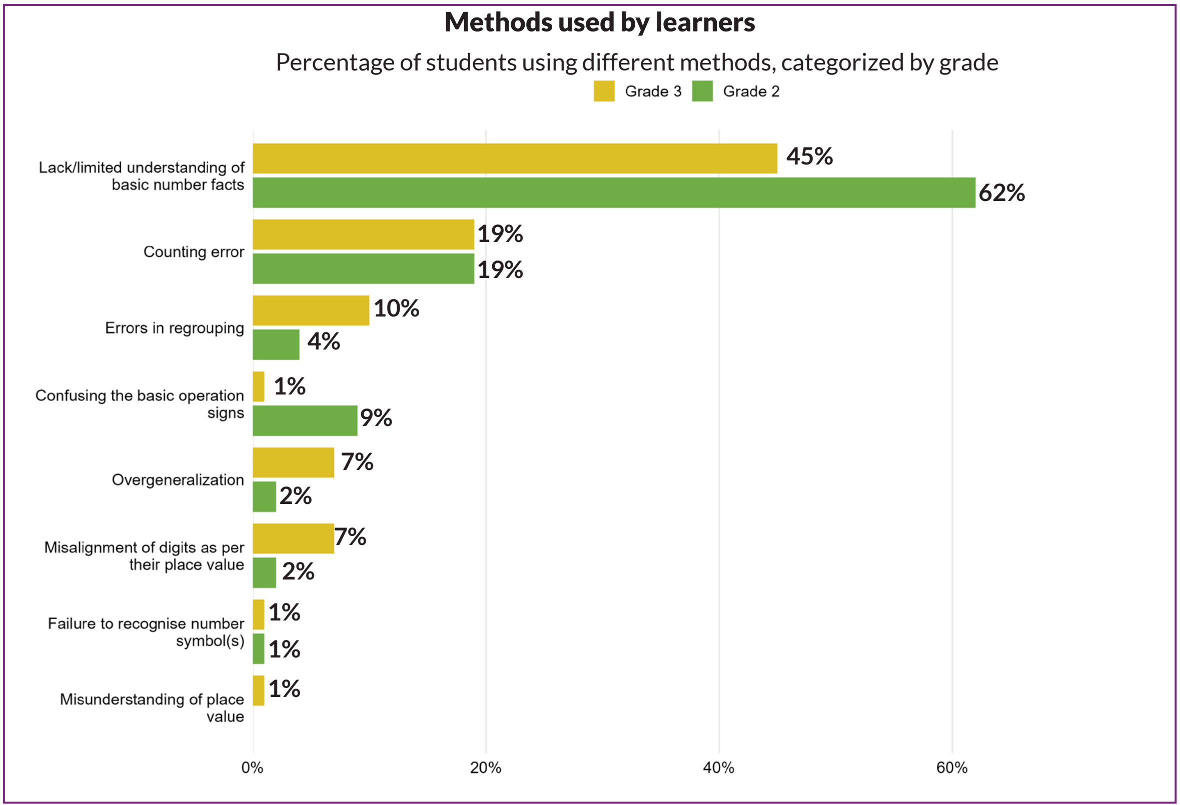


Figure 1: Error types by grade

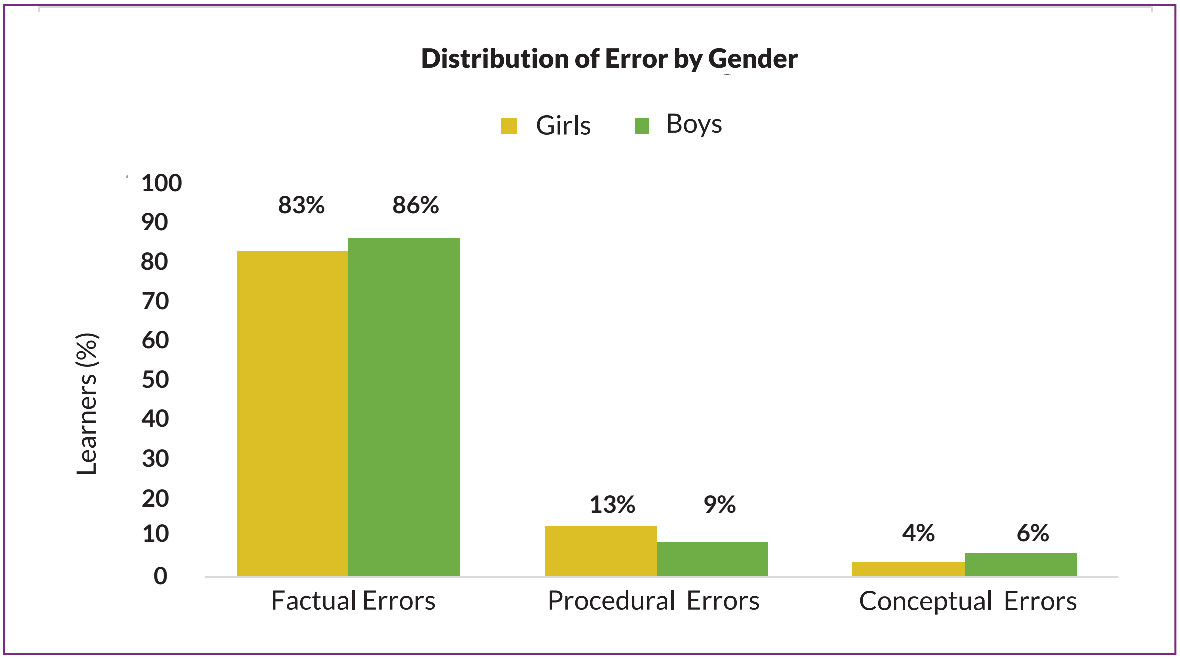
Given the high prevalence of the factual errors observed, there were therefore fewer learners making procedural and factual errors at **194 (11%)** and **84 (5%)** respectively. Similar trends were observed across the two grades:

- In grade **2, 91%** of errors recorded were factual errors (see figure 1). **62%** of these lacked understanding of basic number facts **(62%)**, were confusing the basic signs **(9%)**, had counting errors **(19%)**, or failed to recognize number symbols **(1%)** ***(see figure 2).***
- While **75%** of grade 3 learners made factual errors, this was a decrease in the same errors (i.e., factual) made in grade 2 **(91%),** indicating increased understanding of number facts and operations in grade 3. This implies why there were more learners in grade 3 who made procedural and conceptual errors.



Key Finding 2: Factual Errors were the Most Prevalent across Gender.

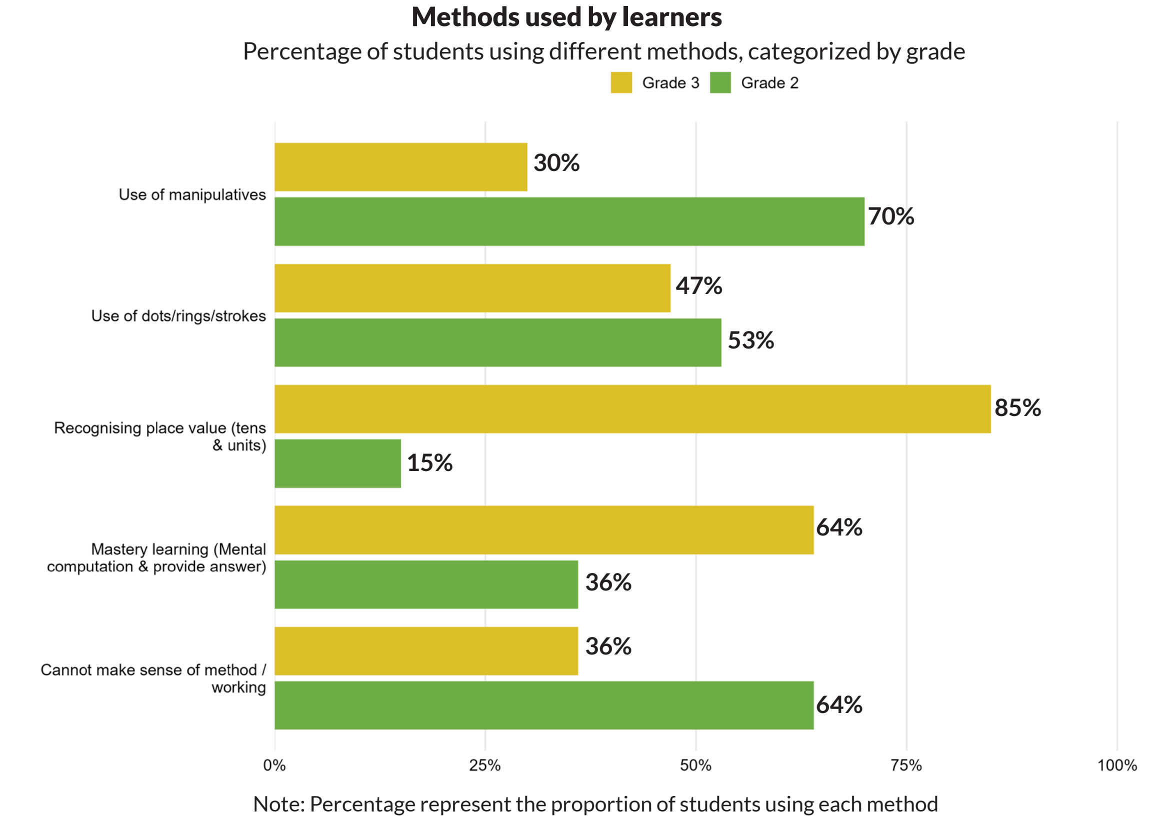
The lack of basic facts and principles affects the accuracy in working out problems in numeracy for boys and girls. Factual errors remained pronounced with slightly more boys than girls recording this error at **86%** and **83%,** respectively.



- Boys and girls performed better in addition tasks when compared to subtraction tasks. However, performance differences were observed across grades. In grade 2, boys outperformed girls in addition tasks, whereas in grade 3, girls outperformed boys in addition tasks. Notably, girls made slightly more procedural and conceptual errors in both grades.

Key Finding 3: Use of Concrete Objects and Tally Marks was the Most Commonly Used Method.

As learners progress to higher grades, it is expected that they will apply high order reasoning and methods to solve numeracy problems. However, the use of tally marks (dots/rings/bundles) was the most commonly used method as it was applied across **55%** of the items. The high prevalence of the use of tally marks suggests its widespread application in foundational tasks, although its effectiveness in addressing more complex tasks might be limited. The graph below shows the prevalence of the various methods observed:



Grade 2

- In Grade 2, the use of tally marks was the most common method, accounting for **706** instances **(53%)** of the total methods used by this grade.
- There were **114** instances **(9%)** where learners used manipulatives.
- There were **68** instances **(5%)** where learners applied their understanding of the place value concept to solve numeracy tasks.
- There were fewer learners observed to use mental math **(50 instances (4%)** to solve the tasks provided.

Grade 3

- In Grade 3, there is a gradual increase in the application of the place value concept to **376** instances (accounting for **85%**), different from 68 instances (**15%**) at grade 2. This reflects alignment with advanced tasks involving place value and regrouping.
- Overall, the use of tally marks by grade 3 learners decreases slightly to **622** instances (**47%**) when compared to grade 2, whereas we observed **89** instances where learners used mental computation.

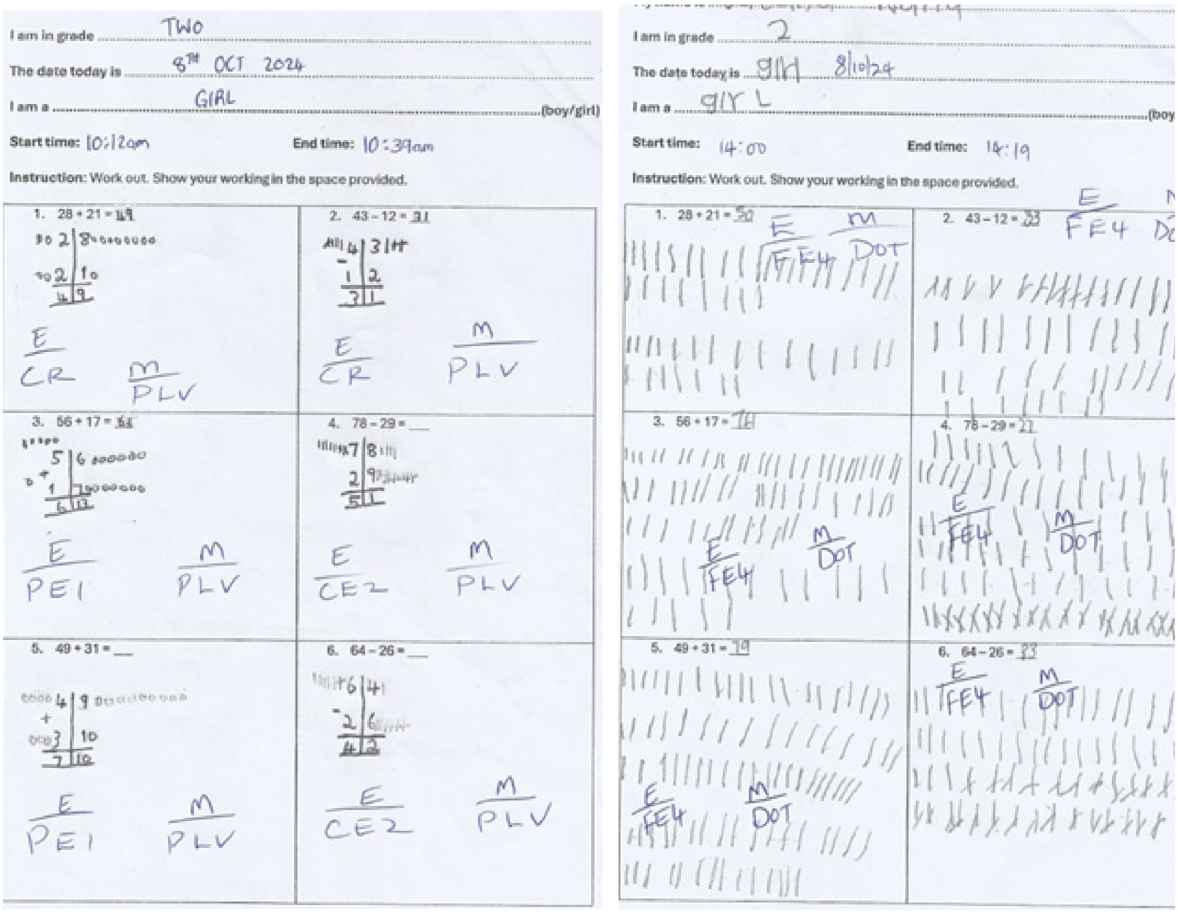


Figure 3: Sample learner scripts

Key Finding 4: The Method Used to Solve Tasks Strongly Influenced the Outcome.

The application of higher order skills, such as use of structured and meaningful strategies like mastery learning and recognizing place value was associated with significantly higher odds of obtaining a correct response. Compared to the reference method ("Unclassified method"), all other methods are associated with significantly higher odds of a correct response.

1. Using mastery learning has the highest odds ratio **(2661.35)**, followed by recognizing place value **(1419.76)** and using dots, rings, or strokes **(521.78).**
2. The use of manipulatives also improves performance, with an odds ratio of **78.72** ***(See Annex 1).*** These results suggest that learners who apply structured and meaningful strategies are much more likely to solve tasks correctly.

This includes workings whose logic could not be mapped on to the defined categories

Key Finding 5: Leverage Promising Classroom Opportunities to Reinforce Reflective Teacher Practices.

From the classroom lesson observations, teachers used a variety of teaching methods, including collaborative group work, peer learning and to some extent, use of manipulatives to demonstrate concepts. There was a deliberate effort by teachers to create a safe learning environment for all learners. This was evident through,

1. **Collaborative Learning:** Group activities were widely used across classrooms, promoting peer learning and interaction. Teachers facilitated collaborative approaches, enhancing learners' understanding of mathematical concepts.
2. **Learner Engagement:** Most learners were comfortable asking questions and discussing their errors. This was particularly evident in classrooms where teachers actively encouraged a collaborative and supportive environment.
3. **Encouraging Growth Mindset:** Most teachers fostered an incremental mindset among learners by encouraging them to view mistakes as opportunities for learning. Practices such as singing, motivational discussions, and active questioning were observed and encouraged to boost learner's confidence, creating a positive atmosphere for addressing errors.

Application of error analysis to inform instruction:

1. **Systematic error documentation:** Teachers identified errors through classwork assignments and questioning. Six out of eight teachers observed and identified errors through corrections and questioning during lessons. However, there lacked systematic approaches in documenting these errors to identify emerging patterns. There is an opportunity to reinforce systematic analysis of errors to reveal patterns and misconceptions through a peer support mechanism at school. This strategy could ease the documentation process in the context of large class sizes and high teacher workload.
2. **Capacities to distinguish error types:** While teachers identified errors, only four out of eight could distinguish between errors caused by misconceptions and those caused by simple mistakes or slips. Subject matter knowledge and pedagogical content knowledge are essential tools teachers will require to effectively identify the reasons behind the observed errors. Focusing on this during in-service teacher training offers a great opportunity to reinforce reflective practice within the early-grade classrooms.
3. **Diagnostic practices:** The use of questioning varied among teachers. Some teachers employed probing techniques to explore learners' thought processes while others limited their methods to general corrections, missing opportunities to provide targeted feedback. Corrections were generalized, with little evidence of actionable insights being drawn from error patterns. To effectively equip learners with the desired factual understanding and mastery of numeracy concepts, teachers must go beyond general feedback to more targeted instruction, aimed at building mastery of foundational concepts.
4. **Instructional practices:** Most teachers did not use error analysis data to inform their instructional practices. This suggests the need for training focused on the integration of error analysis into lesson planning and instructional delivery. The Competence-Based Curriculum (CBC) prioritizes competency acquisition over content coverage. This shift in focus requires a shift in the practices around teacher coaching and mentoring by the headteachers as well as the curriculum support officers. Coaching and mentoring should go beyond teaching to focus more on whether learners have mastered the foundational competencies to thrive at school.

Conclusions and Recommendations for Practice

The **predominance of factual errors** underscores the need for targeted interventions to strengthen the mastery of basic number facts. As learners progress to Grade 3, the rise in procedural errors highlights challenges with regrouping and place value, suggesting a need for structured support in multi-step problem-solving. Gender differences indicate that boys struggle more with factual retention, while girls are more prone to procedural and conceptual errors, reflecting differences in approach rather than ability. Addressing these gaps through differentiated instruction, targeted remediation, and increased use of manipulatives can enhance numeracy learning and reduce error rates across grades.

With progression comes gradual mastery. The transition from Grade 2 to Grade 3 highlights a shift from reliance on foundational methods like Dots/Rings/Strokes (DOT) and unstructured approaches (NON) to more structured strategies such as Place Value (PLV) and Mental Computation (MEN). This progression underscores the need for intentional instructional support to strengthen conceptual understanding as learners advance. While DOT is useful for early numeracy, its continued dominance in Grade 2 suggests a need for diversification of strategies to build problem-solving skills. The gradual adoption of PLV and MEN in Grade 3 indicates growing alignment with complex mathematical tasks, reinforcing the importance of early exposure to these effective methods.

Mental Computation (MEN) stands out as the **most effective method** for problem-solving and reasoning tasks, yet its limited application suggests a need for increased emphasis in early numeracy instruction. Educators should prioritize MEN, especially in higher grades, to strengthen conceptual understanding. Place Value (PLV) also demonstrates reliability but requires refinement to reduce errors and improve efficiency. While Dots/Rings/Strokes (DOT) are widely used for foundational tasks, their lower success rate in complex problem-solving highlights the need for integrating more effective strategies. Addressing the gender and grade-level disparities in method application will ensure all learners benefit from the most effective numeracy approaches.

To enhance numeracy instruction, teachers need structured training on **systematic error documentation, diagnostic techniques, and the integration of error analysis into instructional planning.** The absence of systematic approaches in analyzing errors learners make, limits teachers' ability to identify patterns and design targeted interventions. Encouraging deeper diagnostic practices—such as probing questions to uncover misconceptions—will help address learning gaps effectively. Additionally, integrating error analysis into lesson planning will support adaptive teaching, moving beyond rigid lesson structures. Strengthening collaborative learning approaches and fostering a growth mindset will further empower learners to engage actively with errors as opportunities for growth. Equipping teachers with these skills and resources is essential for improving learning outcomes in early numeracy classrooms.

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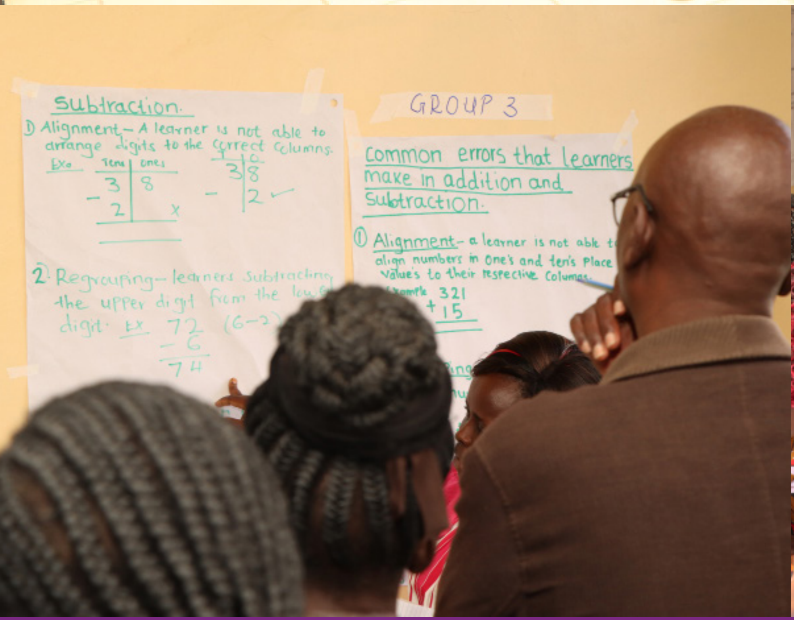
Annex 1: Multilevel Logistic Regression Results

Task Learner response (0=incorrect, 1 = correct)	Odds Ratio.	St. Err.	t-value	p-value	[95% Conf	Interval]	Sig
sk type: base Addition	1	.	.	.	.	.	
Subtraction	.167	.033	-9.00	0	.113	.247	***
Minutes	1.002	.022	0.08	.935	.96	1.046	
Method: base Cannot make sense of method/working	1	.	.	.	.	.	
Mastery learning	2661.345	3164.336	6.63	0	258.836	27363.936	***
Number line	1	.	.	.	.	.	
Recognising place value (tens & units)	1419.76	1668.711	6.18	0	141.826	14212.572	***
Use of dots/rings/strokes	521.783	596.485	5.47	0	55.517	4904.052	***
Use of manipulatives	78.721	105.109	3.27	.001	5.749	1078.018	***
Sex (B/G) : base Boys	1	.	.	.	.	.	
Girls	.989	.261	-0.04	.967	.59	1.658	
Grade: base Grade 2	1	.	.	.	.	.	
Grade 3	3.697	1.056	4.58	0	2.112	6.473	***
ask Number: base Task 1	1	.	.	.	.	.	
Task 2	.294	.05	-7.21	0	.211	.41	***
Task 3	.16	.029	-9.97	0	.111	.229	***
School: base School X1	1	.	.	.	.	.	
School X2	1.618	.695	1.12	.263	.697	3.756	
School X3	.792	.309	-0.60	.549	.368	1.7	
School X4	.6	.278	-1.10	.27	.242	1.488	
School X5	.17	.095	-3.17	.002	.057	.508	***
Constant	.001	.002	-5.38	0	0	.016	***
Children							
var (Task type: Subtraction [children])	2.333	.78			1.211	4.492	
var (Constant[children])	3.779	.681			2.655	5.379	

Mean dependent var	0.279	SD dependent var	0.449
Number of obs	2428	Chi-square	204.823
Prob > chi2	0.000	Akaike crit. (AIC)	1993.804

**** p<.01, ** p<.05, * p<.1*



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