Diagnostic Assessment for Foundational Mathematics Among Class II Students

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Abstract

Foundational mathematics provides the basis for children's subsequent learning and includes competencies related to number, mathematical operations, patterns, shapes, spatial understanding, and the application of mathematical ideas. The present study examined the foundational mathematics performance of Class II students through an item-level diagnostic assessment. The analysis was based on a learner-level dataset comprising 448 Class II students from seven private schools in Rewari district, Haryana, India. The mathematics component included 96 scored items distributed across four domains: Shapes, Number, Mathematical Operations, and Pattern. Item-level correct responses and learner-level scores were analysed using descriptive statistics. The overall mean mathematics score was 48.18, with a standard deviation of 15.28. Domain-level analysis showed substantial differences in performance. Pattern was the strongest domain, followed by Number, Mathematical Operations, and Shapes. At the item level, performance ranged from 96% to only 6%. Within Mathematical Operations, performance varied markedly across items. Multiplication also demonstrated substantial variation. These findings indicate that foundational mathematics achievement is not uniform across competencies and that aggregate scores alone may conceal important learning gaps. The study demonstrates the value of item-level diagnostic assessment for identifying specific areas requiring instructional attention and for supporting competency-oriented mathematics teaching at the foundational stage.

Keywords: Foundational Mathematics, Foundational Numeracy, Diagnostic Assessment, Primary Mathematics, Mathematical Proficiency

1. Introduction

Foundational mathematics is a critical component of early education because children's understanding of number, quantity, operations, patterns, shapes, and spatial relationships provides the basis for later mathematical learning. Early mathematical knowledge is not limited to the ability to calculate; it includes understanding relationships, recognising patterns, representing mathematical ideas, and applying mathematical knowledge to different situations.

The National Education Policy (NEP) 2020 places foundational literacy and numeracy at the centre of school education reform in India. It specifically emphasises foundational competencies in reading, writing, counting, arithmetic, and mathematical thinking and calls for continuous formative and adaptive assessment to track children's learning and support individualised instruction.

The NIPUN Bharat Mission further identifies foundational numeracy as the ability to reason and apply simple numerical concepts in everyday problem solving. Its framework includes pre-number concepts, number and operations, measurement, shapes and spatial understanding, and patterns as important components of early mathematics. The National Curriculum Framework for the Foundational Stage (NCF-FS) 2022 similarly emphasises that mathematical learning should move from simple to complex and should develop children's understanding of numbers, shapes, space, measurement, ordering, classification, and patterns.

These policy directions make assessment particularly important. If foundational mathematics is multidimensional, an assessment that reports only a total score may provide insufficient information for instructional decision-making. A child may perform well in counting but struggle with place value; similarly, a learner may demonstrate reasonable procedural performance in addition but have difficulty with another form of mathematical operation.

Diagnostic assessment provides an opportunity to examine these differences systematically. Rather than asking only how much mathematics a learner has learned, diagnostic assessment can help identify which competencies are relatively secure and which require further support.

The present study therefore examined the foundational mathematics performance of Class II students through an item-level diagnostic analysis. It focused on four mathematical domains represented in the assessment dataset: Shapes, Number, Mathematical Operations, and Pattern.

2. Conceptual Framework

2.1 Foundational Mathematics and Numeracy

Foundational numeracy involves more than the memorisation of number facts or execution of basic calculations. The NIPUN Bharat framework identifies early mathematical learning through competencies such as counting, understanding number systems, performing operations, recognising patterns, and developing spatial and shape-related understanding.

The NCF-FS 2022 emphasises that mathematical learning should progress developmentally from simpler mathematical vocabulary and concepts towards increasingly complex mathematical skills. It specifically identifies concepts related to numbers, shapes, space, measurement, ordering, matching, classification, and patterns.

The assessment domains used in the present study therefore correspond broadly with important areas of foundational mathematics.

2.2 Mathematical Proficiency

The present study is informed by the concept of mathematical proficiency, which can be understood as a multidimensional construct involving conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition. These dimensions are interrelated, and success on an individual mathematical item should not automatically be interpreted as evidence of comprehensive mathematical proficiency. A learner may successfully perform a familiar procedure while experiencing difficulty in recognising mathematical relationships, explaining the underlying concept, or applying the same knowledge in a different representation or context. Conceptual understanding and procedural fluency are therefore best viewed as interconnected aspects of mathematical learning rather than as isolated abilities. Conceptual understanding can support the flexible and meaningful use of procedures, while procedural fluency can provide a foundation for engaging with more complex mathematical ideas. The substantial variation observed across items within the same mathematical domain in the present study supports this perspective and suggests that overall domain-level scores may conceal important differences in the specific competencies and forms of mathematical understanding demonstrated by learners.

2.3 Diagnostic Assessment

Diagnostic assessment is particularly valuable when the purpose of assessment is to identify learners' specific strengths, learning gaps, and instructional needs. Assessment can generate evidence about learners' understanding and provide a basis for making informed instructional decisions. Rather than treating assessment as an endpoint, a diagnostic approach uses assessment evidence to identify areas requiring reinforcement and to guide subsequent teaching and learning. The present study adopts this diagnostic orientation by examining performance at the level of individual assessment items, in addition to overall mathematics scores, to identify specific areas of competency and difficulty across foundational mathematical domains.

3. Review of Literature

Mathematical proficiency is multidimensional and extends beyond the ability to perform calculations correctly. It involves conceptual understanding, procedural fluency, reasoning, problem-solving, and the ability to apply mathematical knowledge in varied contexts (National Council of Teachers of Mathematics - NCTM, 2000). This distinction is particularly important at the foundational stage, where learners may perform familiar procedures but experience difficulty when concepts are presented through different representations or situations.

In the Indian context, NEP 2020 emphasises foundational numeracy, conceptual understanding, problem-solving, and experiential learning rather than rote procedural learning (Ministry of Education, 2020). The NCF-FS 2022 further identifies numbers, operations, shapes and spatial understanding, measurement, classification, ordering, and patterns as important areas of foundational mathematical learning (NCERT, 2022). Similarly, the NIPUN Bharat guidelines emphasise number sense, mathematical operations, shapes and spatial understanding, patterns, reasoning, and the application of mathematical concepts in everyday contexts (Ministry of Education, 2021).

These frameworks indicate that foundational mathematics assessment should capture specific competencies across different mathematical domains rather than relying solely on an aggregate mathematics score. Item- and domain-level analysis can therefore identify particular areas of strength and difficulty and provide more actionable information for instructional planning. For example, identifying difficulty in number comparison or shape recognition is more instructionally useful than describing a learner as generally "weak in mathematics." Such competency-specific assessment is consistent with the broader shift towards competency-based and formative assessment advocated in NEP 2020 and NCF-FS 2022.

4. Research Gap

Although foundational literacy and numeracy have become central priorities in Indian educational policy, there remains a need for detailed empirical evidence regarding the specific mathematical competencies that Class II students have or have not developed.

These issues are particularly important.

- First, overall mathematics scores may conceal substantial differences between individual competencies.
- Second, performance within the same mathematical domain may vary considerably depending on the nature and demand of an item.

The present study addresses these issues through an item-level analysis of foundational mathematics performance among Class II students.

5. Research Questions

The study addressed the following questions:

1. What is the overall foundational mathematics performance of Class II students?
2. Which foundational mathematics domains demonstrate relatively stronger and weaker performance?
3. Which individual assessment items show the highest and lowest levels of correct response?
4. How much variation exists among items within the same mathematical domain?
5. What learning priorities can be identified from the diagnostic assessment?

6. Objectives of the Study

The study was undertaken with the following objectives:

1. To assess the foundational mathematics performance of Class II students.
2. To examine variation in performance among items within the same mathematical domain.
3. To identify areas of foundational mathematics requires greater instructional attention.

7. Methodology

7.1 Research Design

The study employed a descriptive diagnostic assessment design. The objective was to describe students' current foundational mathematics performance and identify specific areas of strength and difficulty through item-level analysis.

7.2 Population and Sample

The population comprised Class II students enrolled in schools across Haryana, India. The study sample consisted of 448 Class II students enrolled in private schools in Rewari district, Haryana, India.

7.3 Tool Used

Self-developed tool 'Achievement Test in Mathematics' used for the study. The assessment tool comprised 96 items. The assessment items were designed across four foundational mathematical domains only: shapes, numbers, mathematical operations, and patterns as mentioned in table 1.

Table 1- Mathematics Domains and Items

Domain	Number of Items
Shapes	20
Number	17
Mathematical Operations	39
Pattern	20
Total	**96**

7.4 Data Analysis

The following descriptive analyses were conducted:

- Mean, Median, Standard Deviation
- Domain-level correct-response rate
- Item-level correct-response rate

8. Results

8.1 Overall Mathematics Performance

Overall mathematics performance is presented in table 2.

Table 2 – Overall Performance Analysis

Statistic	Result
Number of students	**448**
Mathematics items	**96**
Maximum mathematics score	**96**
Mean	**48.18**
Mean percentage	**50.19%**
Median	**47.00**
Standard deviation	**15.28**
Minimum	**17**
Maximum	**89**

The mean mathematics performance is approximately **50.2%**, indicating that, on average, students answered about half of the mathematics items correctly. The relatively large standard deviation of 15.28 indicates substantial variation among learners. This variation is important because a single mean score does not adequately describe the learning profile of the group.

8.2 Distribution of Mathematics Scores

The students are distributed across four broad performance bands based on their mathematics scores out of 96. Table 3 indicating the overall mathematics performance.

Table 3 – Overall Mathematics Performance

Level of Performance	Score Percentage	Mathematics Score	Students	Percentage
Beginner	0–40%	0–38	120	26.8%
Progressing	41–60%	39–57	208	46.4%

Proficient	61–80%	58–76	104	23.2%
Advanced	81–100%	77–96	16	3.6%
Total			**448**	**100%**

The distribution of students across the four levels of mathematics performance indicates that the largest proportion of students (46.4%) were at the **Progressing** level, with scores ranging from 41–60%. A further 26.8% of students were at the **Beginner** level, scoring up to 40%. Meanwhile, 23.2% of students demonstrated **Proficient** performance, with scores ranging from 61–80%, while only 3.6% of students reached the **Advanced** level, with scores between 81–100%. Overall, the findings indicate that most students concentrated within the Beginner and Progressing levels, whereas relatively fewer students demonstrated Proficient or Advanced levels of mathematics performance.

9. Domain-Level Performance

The domain-level analysis produced the following profile i.e. mentioned in table 4:

Table 4 – Domain-level Performance

Domain	Items	Mean Correct-Response Rate
Pattern	20	66.07%
Number	17	51.00%
Mathematical Operations	39	46.79%
Shapes	20	40.22%
Overall Mathematics	**96**	**50.19%**

The domain-level analysis revealed variations in students' performance across the four foundational mathematics domains. Pattern emerged as the strongest-performing domain, with a mean item-level correct-response rate of 66.07%. Number recorded a mean correct-response rate of 51.00%, indicating moderate but uneven performance. Mathematical Operations had a mean correct-response rate of 46.79%, which was slightly below the overall mathematics performance, while Shapes recorded the lowest domain-level performance at 40.22%. Overall, these findings indicate that foundational mathematics achievement was not evenly distributed across the different mathematical content areas, with students demonstrating relatively stronger performance in patterns and comparatively greater difficulty in shapes and mathematical operations.

10. Diagnostic Analysis of Number

The Number domain contained 17 items covering competencies such as counting, sequencing, comparison, number relationships, place value, ordering, even numbers, face value, and skip counting.

Performance varied substantially across these items i.e. shown in table 5.

Table 5 – Analysis of Number Performance

Stronger performance	Lower performance
• Item 21 – Counting: 90% • Item 23 – Counting: 77% • Item 27 – In Between: 79% • Item 29 – Odd Numbers: 66% • Item 36 – Skip Counting: 64%	• Item 37 – Greater Than: 13% • Item 35 – Face Value: 19% • Item 26 – Before: 40% • Item 32 – Ascending: 30% • Item 34 – Even Numbers: 35%

The difference between Item 21 (90%) and Item 35 (19%) is particularly notable. This suggests that students' foundational number knowledge was **uneven rather than uniformly strong or weak**. Basic counting appeared comparatively well established, whereas some number-relational and number-property tasks were substantially more difficult. This finding supports the view that foundational numeracy includes multiple interconnected competencies rather than a single general "number skill."

11. Diagnostic Analysis of Mathematical Operations

Mathematical Operations constituted the largest domain, comprising 39 mathematics items.

11.1 Addition

The addition items presented in Table 6 showed relatively stronger performance overall.

Table 6 – Item Level Analysis of Addition

Items	39	40	41	42	43	44
Correct Responses	79%	68%	54%	65%	65%	72%

The range from 54% to 79% demonstrates that even within addition, performance was not uniform.

11.2 Subtraction

Subtraction demonstrated greater variation in students' performance, as presented in Table 7:

Table 7 – Item Level Analysis of Subtraction

Items	45	46	47	48	49	50	51
Correct Responses	74%	53%	26%	39%	37%	25%	32%

The difference between the highest performing subtraction items (74%) and the lowest (25%) is substantial. This should not be interpreted simply as evidence that "students cannot subtract." Instead, the findings indicate uneven attainment across different subtraction tasks.

11.3 Multiplication

Multiplication also showed marked variation in students' performance across the assessed items. Relatively high performance was observed on Item 54 (82%), Item 55 (84%), and Item 59 (82%), whereas substantially lower performance was recorded on Item 63 (21%), Item 66 (22%), and Item 67 (29%). The approximately 62-percentage-point difference between Item 55 and Item 66 highlights substantial variation in students' performance within the multiplication domain. These findings are consistent with the broader literature on mathematical proficiency, which cautions against interpreting procedural performance as the sole indicator of mathematical competence. Mathematical proficiency encompasses interconnected dimensions, including conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition.

12. Diagnostic Analysis of Pattern

Pattern emerged as the highest-performing mathematical domain, although performance varied across individual items. Relatively strong performance was observed on Item 73 (80%), Item 76 (82%), Item 78 (74%), Item 81 (78%), Item 83 (80%), and Item 87 (75%). In contrast, some pattern-related tasks appeared more challenging, with lower correct-response rates on Item 75 (42%), Item 85 (39%), and Item 89 (36%). These findings indicate that pattern recognition was a relative strength compared with the other mathematical domains assessed; however, students' performance was not uniform across different pattern-related tasks. This variation suggests that while many students demonstrated a developing ability to identify and work with patterns, more complex or differently structured pattern tasks may have posed greater challenges. The importance of pattern learning within foundational numeracy further reinforces the relevance of examining students' performance across different types of pattern-related tasks.

13. Diagnostic Analysis of Shapes

Shapes emerged as the weakest-performing mathematical domain, with an average correct-response rate of 40.22%. Relatively strong performance was observed on Item 1 (96%), Item 5 (74%), and Item 9 (67%). In contrast, substantially lower performance was recorded on Item 20 (6%), Item 14 (11%), Item 12 (12%), Item 18 (13%), Item 4 (20%), and Item 11 (21%). The difference between Item 1 (96%) and Item 20 (6%) is particularly striking, highlighting considerable variation in students' performance across different shape-related tasks. These findings suggest that students' understanding of shapes cannot be adequately represented by a single domain-level score, as some shape-related competencies appear relatively well developed while others require considerable reinforcement. This variation underscores the need for instructional approaches that address specific aspects of spatial and geometrical understanding rather than treating knowledge of shapes as a uniform competency. The findings are also consistent with the NCF-FS emphasis on the progressive development of children's understanding of shapes and spatial relationships.

14. Discussion

The central finding of the study is that foundational mathematics performance among Class II students was highly heterogeneous. The overall mean mathematics performance was approximately 50%; however, domain-level analysis revealed substantial differences across mathematical content areas. Pattern emerged as the strongest-performing domain, whereas Shapes was the weakest, with Number and Mathematical Operations falling between these two domains. More importantly, substantial variation was observed within individual domains. For example, performance across subtraction items ranged from 25% to 74%, multiplication items from approximately 21% to 84%, and shape-related items from 6% to 96%.

These large differences demonstrate that learners cannot be adequately characterised simply as "good" or "weak" in a broad mathematical domain. Instead, diagnostic assessment should identify the specific competencies represented by individual items. This approach is consistent with the competency-based and holistic assessment perspective emphasised in NEP 2020, NCF-FS 2022, and NIPUN Bharat, which promotes assessment of learners' understanding and application of foundational concepts rather than reliance solely on aggregate scores (Ministry of Education, 2020, 2021; NCERT, 2022). Item-level analysis can therefore provide more precise information about learners' strengths and learning gaps and support targeted instructional planning.

The findings are particularly relevant to India's foundational learning agenda. NIPUN Bharat conceptualises foundational numeracy in terms of developing numerical understanding, reasoning, and the ability to apply mathematical concepts in everyday situations, while NCF-FS 2022 emphasises a progressive development of mathematical understanding from simple to more complex concepts (Ministry of Education, 2021; NCERT, 2022). The observed variation across items therefore highlights the importance of moving beyond overall mathematics scores towards competency-specific assessment and targeted instructional support during the foundational stage.

15. Educational Implications

15.1 Use competency-level diagnosis

Teachers should avoid interpreting a low overall mathematics score as evidence of a general mathematics deficit. Instead, assessment results should be used to identify specific competencies that require targeted attention and instructional support. For example, stating that "the learner needs support in number comparison" provides more actionable information for planning instruction than simply stating that "the learner is weak in mathematics." Such competency-specific interpretation enables teachers to identify learning gaps more precisely and design appropriate remedial and enrichment strategies.

15.2 Strengthen number relationships

The results for the Number domain suggest a need for systematic attention to several foundational number concepts, including ordering, before-and-after relationships, place value, number comparison, odd and even numbers, face value, and skip counting. These areas may require targeted instructional support to strengthen students' foundational number sense and ensure a more secure understanding of core numerical concepts.

15.3 Strengthen conceptual learning in operations

The variation observed across addition, subtraction, and multiplication items highlights the importance of developing conceptual understanding alongside computational skills. Instruction should provide students with opportunities to explain mathematical procedures, represent operations using concrete objects and pictures, connect mathematical symbols with quantities, identify relationships among numbers and operations, and apply operations in varied contexts. Such an approach can help learners move beyond procedural recall towards meaningful mathematical understanding and flexible application of skills. This is consistent with the NIPUN Bharat framework, which emphasises the development of conceptual understanding and procedural fluency as complementary aspects of foundational numeracy.

15.4 Strengthen spatial and shape understanding

The low overall performance in the Shapes domain indicates a need for greater emphasis on developing students' understanding of spatial and geometric concepts. Instruction should provide systematic opportunities for learners to identify the properties of shapes, compare different shapes, sort and classify shapes, recognise similarities and differences, distinguish between two-dimensional (2D) and three-dimensional (3D) forms, and use appropriate mathematical language to describe shapes and spatial relationships. Strengthening these competencies can support learners in developing a more meaningful and comprehensive understanding of shapes and space.

15.5 Build on pattern as a relative strength

Pattern was the strongest domain and can be used as a foundation for developing further mathematical reasoning. Instruction can progress from, **recognizing → extending → describing → explaining → creating patterns.**

15.6 Use assessment information for feedback

Assessment should not end with the identification of correct and incorrect responses. Evidence should be translated into feedback and subsequent learning opportunities. Research on feedback indicates that its effect depends substantially on the type and quality of feedback provided.

16. Implications for Diagnostic Assessment Practice

The findings suggest a three-level assessment framework for foundational mathematics.

Level 1: Domain Identification

Determine whether the learner demonstrates relative strength or difficulty in Number, Operations, Pattern and Shapes.

Level 2: Competency Identification

Within each domain, identify the specific competency requiring attention.

Level 3: Instructional Response

Use diagnostic evidence to design targeted learning activities and reassessment.

This approach is more useful than assigning a single overall mathematics grade.

17. Limitations

The study has several limitations.

- The study uses data from seven selected private schools in one district; therefore, findings should not be generalised to all Class II students in Haryana or India.
- The study is descriptive and does not establish causal relationships between school characteristics, teaching practices, or student achievement.
- The assessment dataset contains item-level responses but does not provide sufficient qualitative information to establish the reasons behind individual errors.

18. Conclusion

The present study provides an item-level diagnostic profile of foundational mathematics among Class II students. Based on the learner-level dataset, 448 students were assessed on 96 mathematics items covering Shapes, Number, Mathematical Operations, and Pattern. The overall mean mathematics performance was **48.18 out of 96 (50.19%)**, but the domain-level and item-level findings reveal considerable variation. Pattern was the strongest domain, whereas Shapes was the weakest. Number and Mathematical Operations demonstrated intermediate levels of performance but contained substantial variation among individual items.

The most significant finding is that performance within a mathematical domain was often more variable than the domain-level average suggests. For example, subtraction items ranged from 25% to 74% correct, while multiplication items ranged from 21% to 84%. Shape items ranged from 6% to 96%. These differences demonstrate the limitations of using aggregate achievement scores alone to understand foundational mathematical learning.

The findings support a shift towards diagnostic, competency-oriented assessment, consistent with the foundational learning priorities of NEP 2020, NIPUN Bharat, and the NCF-FS 2022.

At the same time, the findings align with the broader conception of mathematical proficiency in which conceptual understanding, procedural fluency, strategic competence, reasoning, and productive disposition are interconnected dimensions of mathematical learning.

Thus, the major contribution of the present study is not simply to report the mathematics achievement of Class II students, but to demonstrate how item-level diagnostic assessment can uncover specific patterns of mathematical strength, difficulty, and non-response that remain hidden within an overall achievement score.

Such evidence can support more targeted instructional planning and contribute to the broader goal of ensuring that children develop secure foundational mathematical competencies before progressing to increasingly complex mathematical learning.

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