

Development of a Diagnostic Test for Mathematics Learning Difficulties in Elementary School



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KEY WORDS	ABSTRACT
Mathematics Learning Difficulties, Diagnostic Assessment, Elementary Education.	Mathematics learning difficulties at the elementary level remain a significant barrier to academic progress, often going undetected until later stages of education. This study aims to develop a diagnostic test specifically designed to identify mathematics learning difficulties in elementary school students. Employing a qualitative methodology grounded in library research and literature review, this research synthesizes findings from various educational psychology and mathematics education sources. The study explores theoretical frameworks of learning difficulties, cognitive development in children, and best practices in diagnostic assessment design. Key components such as conceptual understanding, computational fluency, problem-solving ability, and number sense were identified as core dimensions often impaired in students with mathematics difficulties. Drawing from over 50 peer-reviewed articles and educational guidelines, the study maps criteria for test construction, including validity, reliability, age-appropriateness, and adaptability to diverse learning contexts. The result is a structured diagnostic prototype that categorizes types of difficulties and aligns them with pedagogical interventions. Findings suggest that an effective diagnostic tool must go beyond performance metrics to include cognitive indicators and learning profiles. This research contributes to the field of educational assessment by providing a foundational model for early detection and support of students at risk of falling behind in mathematics. Future research is recommended to pilot and validate the prototype across various school settings. The study underscores the urgent need for targeted diagnostic tools in addressing learning inequalities and enhancing mathematics instruction at the foundational level.

1. INTRODUCTION

Mathematics is a fundamental subject that shapes logical reasoning, problem-solving skills, and academic success in various disciplines (Stadler et al., 2018). However, a significant number of elementary school students worldwide experience persistent difficulties in learning mathematics, which, if left unidentified and unaddressed, may lead to long-term academic struggles and negative attitudes toward the subject (Csapó & Funke, 2017).

These challenges are not solely due to external factors such as poor instruction or limited resources, but often stem from underlying cognitive or developmental learning difficulties (Pennington et al., 2019). Early identification of these difficulties is therefore essential to providing timely and appropriate educational interventions.

Despite its importance, current practices in diagnosing mathematics learning difficulties in early education remain limited and

inconsistent. Most standardized assessments focus on measuring achievement outcomes rather than identifying the root causes of a student's struggle. This research gap highlights the lack of specialized diagnostic tools that are both context-sensitive and tailored to the developmental stage of elementary learners Santoso, E. B. (2025). Moreover, existing tools are often designed for general learning disabilities and fail to capture specific mathematical constructs such as number sense, spatial reasoning, and arithmetic fluency, which are critical at the primary school level.

Several previous studies have addressed learning disabilities in general education (e.g., Geary, 2011; Butterworth & Laurillard, 2010), but few have focused on developing comprehensive diagnostic instruments dedicated to mathematics learning difficulties. This study introduces a novel framework for designing a diagnostic test based on theoretical constructs and best practices identified through a systematic literature review. The novelty of this research lies in its qualitative approach that integrates findings from educational psychology, curriculum studies, and child development to build a diagnostic model rooted in empirical evidence and pedagogical relevance.

The primary objective of this study is to design a diagnostic test that can identify various forms of mathematics learning difficulties in elementary school students. By providing educators with an effective tool for early detection, the study aims to support differentiated instruction and informed intervention strategies. The broader benefit of this research is to contribute to more equitable learning opportunities and improved outcomes in mathematics education at the foundational level.

2. METHOD

Research Design

This study employed a qualitative research design using the library research method to

develop a conceptual framework for a diagnostic test intended to identify mathematics learning difficulties among elementary school students. The qualitative approach was chosen to facilitate an in-depth exploration of theoretical foundations, empirical findings, and pedagogical models relevant to early mathematics learning and assessment.

Data Sources

The primary data for this study were collected from secondary sources, including academic books, peer-reviewed journal articles, dissertations, policy documents, and official curriculum guidelines. The selection focused on materials published in the last two decades and written in English or Bahasa Indonesia. Key areas of focus included mathematics learning theories, cognitive development in children, diagnostic assessment principles, and prior instruments developed to assess learning difficulties.

Data Collection Techniques

Data collection was carried out through systematic literature review techniques, including:

- Keyword-based searches in academic databases such as ERIC, JSTOR, ScienceDirect, and Google Scholar.
- Inclusion and exclusion criteria to filter relevant sources (e.g., relevance to elementary education, presence of diagnostic components, and methodological quality).
- Manual analysis of bibliographies to identify additional critical sources.

Data Analysis Methods

The collected data were analyzed using qualitative content analysis. This involved:

1. Thematic coding of literature to identify recurring concepts and constructs related to mathematics difficulties.



2. Categorization of assessment dimensions (e.g., number sense, arithmetic fluency, problem-solving ability).
3. Synthesis of theoretical and empirical findings to form a coherent test blueprint and framework.
4. Comparative analysis of existing diagnostic tools to determine strengths, limitations, and gaps.

The findings from the analysis were then used to design a prototype of a diagnostic test, including item categories, indicators, and guiding principles for implementation.

RESULT AND DISCUSSION

The results of this study, based on a qualitative analysis of extensive literature in the domains of mathematics education, cognitive development, and diagnostic assessment, revealed a structured framework for developing a diagnostic test tailored to elementary school students experiencing mathematics learning difficulties. The literature review uncovered that many existing assessment tools prioritize measuring academic achievement or curriculum mastery, rather than diagnosing specific cognitive and conceptual challenges that hinder mathematical learning. This observation confirms the initial research assumption that a specialized diagnostic instrument is needed to support early identification and intervention.

The thematic synthesis identified four major dimensions essential for diagnostic evaluation in mathematics at the elementary level: number sense, arithmetic operations and fluency, problem-solving strategies, and spatial-temporal reasoning. These domains are consistently reported in the literature as areas where learning difficulties most commonly manifest. For instance, deficits in number sense

are frequently associated with dyscalculia and other math-specific learning disorders, while difficulties in arithmetic operations often signal procedural misunderstandings or memory-related issues. The review also indicated that spatial reasoning plays a critical but often overlooked role in understanding geometry and measurement concepts at early educational stages.

Based on these findings, a prototype of the diagnostic test was designed to include items that are developmentally appropriate and aligned with curricular expectations while focusing on the cognitive processes behind mathematical performance. Each item was designed not only to evaluate a student's correctness in answering but also to analyze the underlying strategy or misconception. This dual-focus structure ensures that the test serves both as an assessment tool and a pedagogical guide for teachers.

Furthermore, the study emphasized the importance of qualitative elements in diagnostic assessment, such as open-ended questions, student interviews, and task-based performance, which allow educators to better understand a student's thought process. Literature from constructivist and socio-cognitive perspectives strongly supports the use of these formats in identifying individual differences in learning styles and problem-solving approaches.

The discussion also highlighted the gap between theory and practice in current school assessments. While most national assessments are standardized and summative in nature, they do not provide diagnostic feedback that can inform instructional strategies. This limits teachers' ability to intervene early and tailor instruction according to specific student needs.

The proposed diagnostic test addresses this gap by offering a formative, criterion-referenced tool grounded in empirical research and pedagogical best practices.

Another critical insight gained through this study is the necessity for cultural and contextual relevance. Educational systems vary in curriculum, pedagogical style, and language of instruction, all of which can influence how mathematical concepts are understood and assessed. The diagnostic framework developed in this study is therefore designed to be adaptable, allowing for localization while maintaining a core set of diagnostic indicators supported by global research findings.

Overall, this research not only contributes a theoretically sound diagnostic model but also provides a practical tool that educators can implement to improve early identification and support for students with mathematics learning difficulties. The test's design is intended to be flexible enough for piloting, refinement, and eventual validation through empirical field studies. By bridging insights from literature with diagnostic practice, this study offers a novel contribution to the ongoing efforts in equitable and effective mathematics education.

1. Theoretical Foundations of Mathematics Learning Difficulties

The literature review revealed that mathematics learning difficulties are deeply rooted in both cognitive and affective domains. Children with persistent struggles in mathematics often

exhibit deficiencies in core areas such as working memory, number sense, and symbolic understanding. These difficulties are not merely instructional gaps but are often linked to developmental patterns that require specific and differentiated assessment strategies. The research drew extensively from theories in cognitive psychology, such as Geary's (2004) model of mathematical cognition and Butterworth's (2010) conceptualization of number sense as a foundational construct.

A key insight that emerged was the distinction between general learning difficulties and domain-specific impairments like dyscalculia. While the former may affect learning across subjects, the latter is uniquely tied to numerical processing and problem-solving. The reviewed literature emphasized that early identification of such differences is critical for tailoring interventions. However, most existing diagnostic tools lack the granularity required to distinguish between these categories in early education settings.

Another critical theoretical foundation is Vygotsky's Zone of Proximal Development (ZPD), which suggests that understanding the difference between a child's current ability and their potential performance under guidance is essential. This theory implies that diagnostic tools should not only measure what children know but also assess how they approach tasks, where their reasoning breaks down, and under what scaffolding they perform better.

Table: Comparative Insight Between General Learning Difficulties and Domain-Specific Impairments in Mathematics Diagnosis

Aspect	General Learning Difficulties	Domain-Specific Impairments (e.g., Dyscalculia)	Implications for Diagnostic Design (ZPD-Informed)
Scope of Impact	Affects multiple academic areas (e.g., reading, writing, math)	Primarily affects mathematical cognition and number sense	Tools must isolate math-specific processes from broader cognitive delays
Cognitive Profile	Global cognitive delays (e.g., attention, memory, language)	Selective deficits in numerical reasoning, estimation, calculation	Diagnostic tasks should map domain-specific skill profiles
Common Indicators	Struggles across subjects; generalized academic delays	Difficulty with quantity comparison, number lines, basic operations	Include tasks with increasing complexity to observe where reasoning breaks down
Intervention Approach	Requires broad learning support and strategies	Needs focused numeracy-based remediation strategies	Enables targeted, individualized instructional planning
Assessment Challenge	Often misdiagnosed due to overlapping symptoms	Underdiagnosed due to limited screening in early years	Requires fine-grained, task-based evaluation rather than summative tests
Diagnostic Precision Needed	Moderate; categorized via general achievement testing	High; requires specific probes into numerical cognition	Use of scaffolding to assess learning potential (ZPD-oriented)
ZPD Application	Broad scaffolding across cognitive domains	Specific scaffolding in math-related zones (e.g., quantity to symbol)	Dynamic assessment formats reveal learner potential under guided interaction
Example Tasks in Diagnostic Tool	Reading comprehension, problem-solving across domains	Number comparison, symbolic understanding, missing addends	Tasks paired with teacher prompts to assess conceptual clarity and problem-solving
Literature Insight	Lacks precision in early-grade diagnosis	Emerging focus but still underdeveloped in tools	Diagnostic tools should measure <i>how</i> students think, not just <i>what</i> they know
Required Granularity	Coarse-level screening sufficient for broader planning	High-resolution assessment needed for effective intervention	Include strategy analysis, error-type classification, and reflective prompts

methods and cognitive development stages often result in learning difficulties being misdiagnosed as lack of ability.

In addition to cognitive models, affective factors such as mathematics anxiety and low self-efficacy were also identified as contributing variables. These factors can mask or exacerbate actual cognitive difficulties, leading to

Furthermore, the integration of Piagetian developmental stages into diagnostic design proves valuable. Understanding whether students are in the concrete operational or transitional stages impacts how they engage with mathematical abstractions. Literature showed that mismatches between instructional

inaccurate assessment outcomes if not considered during the diagnostic process. Therefore, a comprehensive tool must account for both observed performance and behavioral indicators of anxiety or confusion.

The results also showed a convergence in recent studies emphasizing multi-dimensional assessment models. Rather than assessing only right or wrong answers, these models analyze patterns in error types, response time, strategy use, and metacognitive behaviors. The implication for the present research is the need for diagnostic instruments that incorporate qualitative observations into structured assessments.

In sum, the theoretical landscape establishes a strong case for developing a diagnostic test grounded in cognitive developmental theory, informed by affective considerations, and designed to distinguish specific subtypes of learning difficulties in mathematics. This insight guided the formation of the test dimensions and item construction principles in the present study.

2. Diagnostic Dimensions Identified from the Literature

From the reviewed literature, four primary dimensions were consistently associated with mathematics learning difficulties in elementary students: number sense, arithmetic operations and fluency, mathematical problem solving, and spatial-temporal reasoning. Each of these domains reflects a core competency that is vital to success in school mathematics and is sensitive to developmental delays or learning disabilities.

Number sense, often referred to as intuitive grasp of numbers, emerged as the most foundational construct. Students with weak

number sense struggle with tasks involving estimation, magnitude comparison, and place value understanding. Studies by Jordan et al. (2009) and Gersten et al. (2005) confirmed that deficits in number sense in early grades predict persistent mathematical underachievement through later school years. Thus, number sense was identified as a critical component of the diagnostic framework.

Arithmetic fluency, including both computation accuracy and speed, also stood out as a core dimension. However, literature emphasized that fluency must not be assessed in isolation. The automatic recall of basic facts often masks conceptual misunderstandings or compensatory strategies. The diagnostic tool proposed in this study therefore includes items that assess both procedural execution and the conceptual rationale behind it, allowing educators to distinguish between memorization and true comprehension.

Problem-solving abilities encompass logical reasoning, language comprehension, and application of strategies to unfamiliar contexts. Several studies emphasized that problem-solving difficulties often arise not from poor computation, but from weak comprehension of mathematical language and inability to visualize or represent the problem. Diagnostic tools must therefore probe how students interpret and translate verbal problems into mathematical representations.

Spatial-temporal reasoning, though less commonly assessed, plays a key role in geometry, measurement, and even arithmetic. Literature by Mix and Cheng (2012) showed that children's early spatial skills correlate strongly with later mathematics achievement. Students with poor spatial reasoning may struggle with symmetry, shape decomposition,

and visualizing transformations. The inclusion of this dimension adds depth to the diagnostic tool, ensuring it captures non-numerical forms of mathematical thinking.

Additionally, the study considered cross-cutting dimensions such as metacognition and error analysis. The diagnostic test was designed to collect data on students' thought processes, confidence ratings, and typical error patterns, which can be interpreted for both formative and diagnostic purposes. This design principle is consistent with recent calls for more dynamic and responsive assessment models.

Collectively, the identification and inclusion of these four core domains and cross-cutting indicators ensure the diagnostic tool covers a comprehensive spectrum of mathematical competencies while maintaining focus on areas most indicative of learning difficulty.

3. Analysis of Existing Diagnostic Instruments

To inform the development of the prototype, a comparative analysis was conducted on existing diagnostic instruments such as the KeyMath Diagnostic Assessment, the Test of Early Mathematics Ability (TEMA), and the Dyscalculia Screener. While each of these tools provides insights into certain aspects of mathematics learning, limitations were observed in terms of cultural adaptability, developmental appropriateness, and integration of qualitative feedback.

The KeyMath instrument, for example, offers a detailed breakdown of mathematical skills but is highly dependent on language-heavy instructions, which may not be suitable for early elementary students or those in multilingual contexts. Additionally, the cost and proprietary nature of such tools limit their accessibility for public schools, particularly in low-resource

settings. These constraints underscore the need for a more adaptable and teacher-friendly diagnostic framework.

The TEMA test, though useful for early identification, focuses heavily on curriculum alignment rather than cognitive diagnosis. It emphasizes score-based classification without probing the reasoning behind errors or the strategies employed. This restricts its utility in understanding individual learner profiles and planning personalized interventions.

The Dyscalculia Screener, while focused on numerical cognition, tends to classify learners into binary categories without acknowledging the spectrum of mathematical understanding. Moreover, it does not cover spatial reasoning or problem-solving components, which are essential to holistic diagnosis. These insights were crucial in guiding the design of a test that avoids such oversights.

What distinguishes the current study's approach is its integration of multiple domains and its use of qualitative data alongside quantitative indicators. By allowing teachers to record observations and student explanations, the diagnostic tool enhances the interpretive value of each item. This dual approach supports a more nuanced understanding of student needs.

Another advantage of the proposed tool is its flexibility. Unlike commercial assessments, it can be adapted to fit local curricular standards, linguistic contexts, and instructional approaches. This increases its potential for broad implementation and cross-cultural relevance, which are often lacking in standardized instruments.

The comparative analysis thus validated the

initial hypothesis: there is a critical need for a comprehensive, theory-based, and adaptable diagnostic tool for mathematics learning difficulties at the elementary level. The findings directly influenced the prototype structure, ensuring it addresses the documented limitations of existing tools.

4. Development of the Diagnostic Test Blueprint

Drawing upon the thematic insights and comparative analysis, the study constructed a prototype blueprint for a diagnostic test comprising 30–40 items, distributed across four core domains. Each item was designed to probe not only mathematical knowledge but also underlying thought processes, common misconceptions, and cognitive strategies. The test incorporates both closed-ended and open-ended items, ensuring both standardization and depth of information.

In the number sense section, items require students to estimate quantities, identify patterns, and compare magnitudes without explicit computation. These tasks are designed to reveal students' intuitive number reasoning and their flexibility in numerical thinking. Teacher observation checklists accompany these tasks to capture non-verbal cues, such as hesitation or reliance on counting aids.

Arithmetic tasks include both basic operations and contextualized computations. These items are structured to detect rote versus conceptual understanding, with partial credit awarded for strategy demonstration. An embedded error analysis rubric enables educators to classify errors (e.g., inversion, misalignment, recall failure) and track student-specific patterns.

Problem-solving tasks present real-world scenarios that require translation from

language to mathematics. Students' responses are analyzed based on their approach to identifying relevant information, selecting operations, and justifying their answers. This section emphasizes cognitive load, perseverance, and reasoning over sheer accuracy.

Spatial-temporal tasks involve shape recognition, pattern extension, and visualization challenges. Items are supported by manipulatives or visual aids where necessary. These are assessed through performance tasks and drawing exercises, which allow for a broader range of student expression and insight into spatial reasoning abilities.

Each item is linked to a diagnostic indicator and accompanied by scoring rubrics and reflection prompts for students and teachers. The test is designed for flexible administration, either individually or in small groups, to accommodate differentiated instruction and reduce test anxiety.

Overall, the blueprint represents a novel diagnostic approach that combines empirical research, developmental theory, and classroom practicality. Its structure is intended to be refined through field trials and feedback from practitioners, forming the basis for a scalable, evidence-based assessment model.

5. Educational Implications and Future Directions

The development of this diagnostic test prototype has significant implications for mathematics education, particularly in early intervention and instructional planning. By providing a tool that moves beyond standardized testing and into the realm of formative diagnostics, educators are better equipped to understand not just what students

get wrong, but why they struggle.

One of the key implications is the enhancement of teacher decision-making. Teachers often lack diagnostic resources that guide targeted instruction. With this tool, they can identify specific areas of weakness, such as conceptual confusion in place value or procedural errors in subtraction, and respond with customized support. This approach promotes a shift from reactive to proactive teaching.

Additionally, the test fosters reflective teaching and learning. By including qualitative elements such as strategy reporting and confidence ratings, both students and teachers engage in deeper metacognitive practices. This aligns with contemporary pedagogical frameworks that advocate for learner agency and self-regulated learning.

For school administrators and policymakers, the diagnostic test offers a means of identifying systemic gaps and allocating resources effectively. Patterns in diagnostic data can inform teacher training, curriculum development, and targeted intervention programs. This makes the tool valuable not only at the classroom level but also for broader educational planning.

Furthermore, the test can contribute to research in educational psychology and special education. It provides a structured yet flexible instrument for investigating how various cognitive factors correlate with specific mathematical difficulties, allowing for more nuanced theoretical development and validation.

The present study recommends pilot testing and psychometric validation of the diagnostic tool across diverse educational contexts. This

includes adapting the tool linguistically and culturally, assessing reliability and construct validity, and refining scoring rubrics. These steps are essential for the tool to gain credibility and widespread adoption.

In conclusion, the diagnostic test developed in this study represents a significant step toward bridging the gap between theory and practice in early mathematics education. It offers a structured, evidence-based, and flexible approach to identifying learning difficulties, empowering educators to provide more equitable and effective instruction for all students.

3. CONCLUSION

The development of a diagnostic test for mathematics learning difficulties in elementary school provides a critical foundation for early identification and targeted intervention of students at risk of falling behind in mathematics. Grounded in cognitive development theories and informed by a comprehensive literature review, the diagnostic prototype integrates core domains such as number sense, arithmetic fluency, problem-solving ability, and spatial-temporal reasoning. By incorporating both qualitative and quantitative elements, the test goes beyond surface-level assessment to uncover the underlying cognitive and conceptual challenges students face. This tool holds significant potential to enhance instructional responsiveness, support differentiated teaching strategies, and contribute to more equitable learning outcomes in foundational mathematics education.

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