Conceptualizing and Assessing Math Learning Disabilities

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Overview

I. What is a Math Learning Disability?
Theoretical ~ Operational ~ Empirical

II. What Does a Math Disability Look Like?
Math Difficulties ~ Processing Deficits ~ Other Experiences

III. Developing Thoughtful MLD Assessments
Rule Outs ~ Math Skills ~ Processing ~ Challenges

IV. Case Study

I. WHAT IS A MATH LEARNING DISABILITY?

What is a Math Learning Disability?

"Dyscalculia" ***"Math Learning Disability"***
"Specific Learning Disability" ***"MD"***
"MLD" ***"Math Learning Differences"***
"Specific Learning Disorder" ***"Dysgraphia"***
"Dyslexia" ***"Math Learning Difficulties"***

Professionals and academics have different definitions and understandings of what a math learning disability is depending on their training, fields of expertise, and professional goals.

What is MLD (SLD)? *SPSY Theoretical Perspective*

Specific learning disabilities are:

- Endogenous
- Neurologically-based
- Deficits in cognitive processes that interfere with acquisition of academic skills
- Heterogenous

(NASP, 2011)

What is MLD (SLD)? *Operational Definition*

IDEA, 2004

*A disorder in one or more of the basic **psychological processes** … may manifest itself in the imperfect ability to listen, think, speak, read, write, spell, or **do mathematical calculations**.*

CA Ed Code

Processing Deficit
- Attention Processing
- Auditory Processing
- Visual Processing
- Sensorimotor Processing
- Cognitive Abilities

Math Deficit
- Math Calculation
- Math Problem Solving

What is MLD?
Empirical Findings / Math Deficits

Geary (1993, 2010), Geary et al. (2011)

- Math fact retrieval, execution of arithmetic procedures, implicit understanding of exact quantity and approximate magnitude, visuospatial math representations
- Use of developmentally immature arithmetical procedures and high frequency of procedural errors

UK Department of Education (from Butterworth)

- Difficulty understanding simple number concepts, lacking intuitive grasp of numbers, difficulty learning number facts and procedures

What is MLD?
Empirical Findings / Processing Deficits

Potential Processing Delays

Working Memory (Feifer, 2005; Geary et al., 2011)

- Central executive working memory
- Phonological loop
- Visual-spatial sketchpad

Processing Speed (Geary et al., 2011)

Low-average IQ (Geary et al., 2011)

Visual perception (Feifer, 2005)

Lack of Sufficient Research

"There is no convincing evidence implicating any form of working memory as a causal feature in dyscalculia...

There is no convincing evidence to show that spatial deficits in themselves lead to DD."

(Butterworth, 2005, p. 461)

Note: Findings are constrained by participant selection

What is a Math Learning Disability?

As school psychologists, we know that mathematics learning disabilities are ***brain-based***; students with MLD struggle with math due to delays and differences in the ways that their brains process information.

There is insufficient academic research to fully support a conceptualization of a MATH Learning Disability that is consistent with IDEA/Ed Code and NASP's guidelines for SLDs (i.e., no agreed-upon neuropsychological processing profile). We're not there yet.

School psychs must use their discretion when diagnosing MLDs.

II.
WHAT DOES A MATH LEARNING DISABILITY LOOK LIKE?

What Does MLD Look Like?
Big Picture /Macro-Level View

A **brain-based** difficulty learning and/or doing grade-level math in age-appropriate ways with regard to *strategies and skills* used and *time* and *effort* expended.

Students have average to superior cognitive abilities, which often includes strong conceptual math understanding and quantitative reasoning skills.

Unless there are other disabilities involved, students tend to be strong in other academic areas and are often described as strong students (which contributes to the under-identification of MLD).

What Does MLD Look Like?
Observed Math Difficulties

ARITHMETIC

- Difficulty with math fact automaticity
- Developmentally immature methods
- Learning and doing math takes longer
- Basic calculation mistakes
- Difficulty with math requiring math fact automaticity (e.g., factoring, division)

ALGEBRA

- Basic calculation errors
- Operations and procedures become confused as work becomes more visually complex and/or problems have more steps

GEOMETRY

- Difficulty visualizing shapes and their attributes
- Difficulty perceiving part-whole relationships
- Difficulty rotating and manipulating orientation mentally

GRAPHING

- Disoriented on coordinate plane
- Difficulty counting to plot points & visually identifying (x,y)
- Difficulty visualizing/perceiving slope
- Difficulty plotting a function mentally

What Does MLD Look Like?
Observed Processing Deficits

Most students exhibit delays in visual processing

- Visual memory
- Visual-spatial reasoning
- Visual-spatial perception / processing (e.g., part-whole perception, perceiving line orientation, mental rotation)
- Visual Processing Speed

Executive Functioning-related difficulties (e.g., symptoms of ADHD & ASD) may also contribute to math learning challenges. Is this MLD?

What Does MLD Look Like?
Observed Math Learning Experiences

Difficulty applying knowledge and skills to solve problems – Students can do one thing at a time, but lose it when they have to put it all together.

Cognitive overload -- The demands of doing math may exceed students' cognitive capacity when juggling visual perception, visual memory, calculation, retrieving prior knowledge, spatially organizing thinking, and engaging in problem solving/reasoning etc…

Math takes more time – Students with MLD need more time to process, reason, and keep cognitive load low.

Appearance of careless errors – Errors that appear to be "careless" or "lazy" are usually a symptom of calculation difficulties &/or cognitive overload

Number throwing/avoiding deep thinking: When problems look or feel too hard, students may avoid thinking by guessing at operations and procedures.

What Does MLD Look Like?
Social-Emotional Experiences

Daily Experiences	Long-Term Effects
Feelings	Feelings
Anxiety / Stress / Panic	Panic & Pressure
Shame / embarrassment	Quicksand, dark clouds, & despair
Hopelessness / depression	Shame and Alarm
Anger	Really uncomfortable emotions
Triggers	Consequences
Taking tests	Low self-confidence
Asking questions	Decreased effort/motivation
Contributing to discussions	Self-harm
Watching peers "get it"	Avoidance
Seeking help	Pervasive negative mood

III.
DEVELOPING A THOUGHTFUL MLD ASSESSMENT

Assess MLD in Two Grain Sizes

Zoom In ⟷ **Zoom Out**

Formal testing and data collection:

1) Math Delays
2) Processing Delays
3) Social-Emotional & Behavioral Functioning (general & math-specific)

Look for a **brain-based** difficulty learning and/or doing grade-level math in age-appropriate ways with regard to *strategies and skills* used, *time* and *effort* expended, and impact on the child

I.e., What is the story of how the delays identified impact a student's math learning experience?

Rule-Outs

Access to instruction

- Developmentally appropriate instruction (e.g., content, pace, format, accessibility)
- Student presence & effort

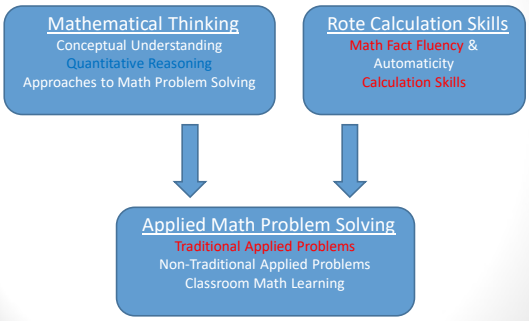
Skills needed to learn math

- Math skills (e.g., prior knowledge, metacognition, thinking vs. memorizing)
- Active learning skills (e.g., note-taking, help-seeking, learning from the work)

Social-Emotional Factors

- Beliefs
- Appropriate learning environment

Math Skills and Abilities



Math Fact Fluency & Automaticity

Assessment Measures

WIAT-III:
- Addition Fluency
- Subtraction Fluency
- Multiplication Fluency

WJ-IV-ACH:
- Math Facts Fluency

Score Validity

- Tests measure how quickly and accurately a student can answer basic math facts when they can focus 100% of their attention, effort, and cognitive load on this single test for 1-3 minutes
- Tests do not measure automaticity; do not tell you that a student has mastered/memorized the facts and can pull them from memory with relative ease and simplicity, regardless of speed.

Math Facts Fluency & Automaticity (cont'd)

Average math fluency scores sometimes mask underlying math fact automaticity difficulties

Students with well-developed calculation strategies can score in the average range under the testing conditions through hard work / effort
- 6x4 → 6x2 = 12 → 12 + 12 → 12 + 8 + 4 → 20 + 4 → 24
- 6x4 → 6x5 = 5, 10, 15, 20, 25, 30 → 30 – 6 → 24
- Quick finger counting

These strategies may work well to compensate for lack of math fact mastery on a 1-3 minute fluency test, but they are often not sufficient to support math thinking in actual math learning contexts with higher cognitive demands. These strategies won't help with factoring, division, etc.

Supplementary Assessment:
- Student interview to determine math fact *automaticity*
- Qualitative observations

Calculation Skills

Assessment Measures

WIAT-III:
- Numerical Operations

WJ-IV-ACH:
- Calculation

KeyMath3 (KM3):
- Mental Math
- Addition & Subtraction
- Multiplication & Division

Score Validity

- Tests measure how many correct answers students can derive on a series of rote calculation skills
- Tests do not assess HOW the student derived the answers

Calculation Skills (cont'd)

Average math calculation scores can sometimes mask underlying calculation difficulties

Students may solve problems in ways that are sufficient for getting average WIAT/WJ scores, but are not sufficient for actual classroom math learning:
- Using developmentally immature strategies
- Taking a lot of time to solve problems that should be solved quickly
- Exerting more focus and effort than is reasonably expected
- Guessing and/or making several attempts to find feasible calculation strategies

Applied Problem Solving

Assessment Measures

KM3: Applied Problems

WIAT-III: Math Problem Solving

WJ-IV-ACH: Applied Problems

Score Validity

- Tests measure how many correct answers students can derive on a series of math word problems
- Tests do not assess HOW the student derived the answers, nor do they assess general math problem solving abilities

Applied Problem Solving (cont'd)

Average problem solving scores can sometimes mask underlying difficulties experienced during the problem solving, including calculation and math fact challenges

Many problems are traditional calculation math problems using words, which are different from non-traditional problems which require different types of thinking and problem solving skills

Students may solve problems in ways that are sufficient for getting average WIAT/WJ scores, but are not sufficient for actual classroom math learning:

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Mathematical Thinking

Assessment Measures	Notes
CONCEPTUAL UNDERSTANDING KM3: • Numeration • Algebra • Geometry	• Mathematical thinking abilities CANNOT be inferred from calculation subtest scores
QUANTITATIVE REASONING WJ-IV-ACH: Number Matrices DAS-II: Sequential & Quantitative Reasoning	• Students with calculation difficulties often have average to superior math thinking skills, which supports SLD diagnosis
PROBLEM SOLVING KM3: Foundations of Problem Solving	• This testing is generally part of a standard battery, but can provide very useful information

Qualitative Math Assessment

Observations (testing & classroom):

- Typical vs. immature procedures
- Counting on fingers, "side math," whispering, finger writing
- Patterns and types of errors
- Misconceptions and holes
- Visually-related mistakes
- How student utilizes and demonstrates number sense
- Emotional experiences

Supplemental Assessment:

- Interview students after the subtest is completed
- Think-aloud problem solving interview using similar problems
- Qualitative observations
- Watch the clock / use a timer

Math Assessment Challenges

Standardized math assessment batteries are limited

- Not many options
- Content is not comprehensive; doesn't cover all areas of math learning that happens in classroom
- Tests are not designed to screen for MLD

WIAT-III & WJ-IV-ACH scores don't give the full picture

- Low scores can be indicative of other non-MLD learning challenges
- High scores may mask true difficulties

School Psychs usually don't do academic assessment

Thorough math assessment takes more TIME and resources

Assessors often need more training/knowledge of math to understand & identify delays/difficulties

Standardized Processing Subtests

VISUAL MEMORY

- NEPSY-II: Memory for Designs
- DAS-II: Recall of Designs, Recognition of Pictures
- WRAML-2: Design Memory/Recog, Picture Memory/ Recognition
- WISC-V: Picture Span

**Compare diffuse vs. discrete, meaningful vs. abstract, content vs. spatial, etc*

VISUAL SPATIAL REASONING

- WISC-V: Visual Puzzles & Block Design
- DAS-II: Pattern Construction

VISUAL SPATIAL PROCESSING

- NEPSY-II: Picture Puzzles, Geometric Puzzles, Arrows

VISUAL-MOTOR INTEGRATION

- Beery VMI

VISUAL PROCESSING SPEED

- WISC-V: PSI, NSI
- DAS-II: Speeded Naming, SIP

ATTENTION / EXECUTIVE FUNCTIONING

- NEPSY-II
- DKEFS

QUANTITATIVE REASONING

- WJ-IV-ACH: Number Matrices
- DAS-II: SQR

CONCEPTUAL MATH UNDERSTANDING

- KM3: Numeration, Algebra, Geometry

Processing Assessment Challenges

Limited by current test batteries – Do we have what we need to identify the underlying processing challenges?

Due to lack of research and consensus in the field connecting specific processing deficits to MLD, school psychs don't have a definitive conceptual or theoretical framework to guide assessment.

Processing delays are often missed.

Round out the Story with Additional Data Collection

Math History (Review of Records & Interviews) -- How long has the difficulty existed, what are past interventions and their results, what do test scores and report cards show?

Social-Emotional Functioning (DAP, 3 Wishes, Sentence Completion, Clinical Interview) – Look for emotional themes related to math (e.g., anxiety, confidence, sadness) and attitudes

Current Classroom Functioning (Observation, work analysis, interviews) – What does the student look like in the classroom, how does student experience math instruction, what is the math output, what are potential environmental impacting factors?

IV. CASE STUDY

Case Study: Background

Referral Question: Fifth grade student exhibits significant difficulties in mathematics despite excellent effort, motivation to learn, and age-appropriate to superior performance in all other academic areas

Background Information:

- Parent reports math struggles have persisted for several years despite multiple private interventions
- Teacher reports student exhibits weak calculation skills and gets lost when solving math problems because she can't hold all of the information and thinking in her head. Student writes a lot of numbers on her paper in disorganized fashion, then erases them because her paper gets cluttered. Student's thinking and reasoning skills are helping her to get by in math, but they are not getting her all the way there.

Case Study: Math Functioning

Key Math-3 Diagnostic Assessment

Composite/Subtest	SS	%ile	ScS	Range
Basic Concepts	**102**	**55**		**Average**
Numeration			11	Average
Algebra			12	Average
Geometry			10	Average
Measurement			9	Average
Data Analysis and Probability			10	Average
Operations	**105**	**63**		**Average**
Mental Computation and Estimation			12	Average
Addition and Subtraction			10	Average
Multiplication and Division			11	Average
Applications	**111**	**77**		**Average**
Foundations of Problem Solving			12	Average
Applied Problem Solving			13	Average
Total Test	**104**	**61**		**Average**

Woodcock-Johnson Test of Achievement, Fourth Edition (WJ-IV-ACH)

Subtest	SS	Range
Number Matrices	117	Superior
Math Facts Fluency	105	Average

Wechsler Individual Achievement Test, Third Edition (WIAT-III)

Subtest	SS	Range
Math Fluency		
Addition	115	Average
Subtraction	90	Average
Multiplication	108	Average

Case Study: Cognitive Functioning

Wechsler Intelligence Scale For Children – Fifth Edition (WISC-V)

Composite/Subtest	SS	%ile	ScS	Range
Verbal Comprehension	**113**	**81**		**Average**
Similarities			11	Average
Vocabulary			14	Superior
Visual Spatial Reasoning	**81**	**10**		**Below Average**
Block Design			7	Below Average
Visual Puzzles			6	Below Average
Fluid Reasoning	**100**	**50**		**Average**
Matrix Reasoning			10	Average
Figure Weights			10	Average
Working Memory	**103**	**58**		**Average**
Digit Span			10	Average
Picture Span			11	Average
Processing Speed	**98**	**45**		**Average**
Symbol Search			8	Average
Coding			11	Average

Developmental Neuropsychological Assessment (NEPSY-II)
Select Visuospatial Processing Subtests

Subtest	ScS	Range
Arrows	8	Average
Geometric Puzzles	8	Average
Picture Puzzles	8	Average

Developmental Neuropsychological Assessment (NEPSY-II)
Select Memory and Learning Subtests

Subtest	ScS	Range
Memory for Designs		
Content Score	3	Far Below Average
Spatial Score	8	Average
Overall Score	4	Below Average

Differential Ability Scales, Second Edition (DAS-II)
Select Subtests

Subtest	T-Score	Range
Recall of Designs	32	Below Average
Recognition of Objects	40	Low Average

Case Study: More on Math Functioning

From test observations and verbal reports:

- Difficulty executing multiple calculations in her head, but able to solve with great effort and multiple attempts
- Has not mastered all of her addition facts and makes calculations in her head for many facts
- Does not know most of her subtraction facts, calculates mathematical differences using immature strategies (e.g., what plus 2 equals 4)

Case Study: Diagnostic Impressions

Areas of Delay/Deficit

- Math deficits in math fact automaticity and math reasoning (i.e., drawing upon math concepts, facts, & procedures to solve math problems)
- Processing deficits in visual-spatial reasoning and visual memory, borderline difficulties with visual-spatial processing

High Math Score vs. Classroom Performance:

- Math test results reflect high effort, unlimited time, and immature strategies
- Compensatory factors not sufficient to support classroom math learning
- Student's cognitive load is exceeded during classroom instruction:
  - Engaging in compensatory learning strategies to operate and reason
  - Deciphering visual information with visual processing delays
  - Focusing on new learning material
  - Monitoring her understanding
  - Remaining on-track with the class…

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