Early Numeracy Screening and Instruction in LRSD

This document outlines LRSD's evidence-based approach to early numeracy screening and instruction, detailing assessment tools, instructional strategies, and support systems to identify and address student needs from Kindergarten to Grade 4 in both English and French programs.

DIVISION SCOLAIRE
LOUIS RIEL
SCHOOL DIVISION

TABLE OF CONTENTS

Executive Summary p.3

Early Numeracy Screening and Instruction in LRSD p.6

Number Knowledge p.8

Number Relations p.11

Number Operations p.15

Fraction Concepts p.18

The Comprehensive Test of Phonological Processing (CTOPP-2) p.20

Practices for Early Screening p.22

Numeracy Screening in French Immersion p.23

Numeracy Screening for Multilingual Learners p.24

Optimizing Class time for a Comprehensive Approach to Early Numeracy Instruction p.25

Roles and Responsibilities p.29

Recording and Reporting Requirements p.31

Early Math Assessment (EMA) Schedule p.32

Executive Summary

Introduction

The Early Numeracy Screening and Instruction initiative in the Louis Riel School Division (LRSD) aims to support early numeracy development through evidence-based screening tools and recommended practices. LRSD would like to acknowledge the contributions made to this document by Dr. Jo-Anne Lefevre and Dr. Heather Douglas from the Department of Cognitive Science at Carleton University. Their "Early Math Assessment @ School Interpretation Guide Version 5.01: December 2025" was used with their permission as a primary source in developing this document.

Overview

The Louis Riel School Division (LRSD) employs a universal early numeracy screening tool called the Early Math Assessment @ School (EMA@School) to support strong numeracy outcomes for all students from Kindergarten to Grade 4. The screening tool, based on research from Carleton University, targets foundational numeracy skills across three main domains: Symbol Knowledge, Number Relations, and Number Operations. These assessments identify student strengths and specific needs, helping teachers plan responsive instruction and interventions. The assessment is administered in the language of instruction for both English and French Immersion programs.

Key EMA@School Components by Grade

The following outlines the key components of EMA@School by grade level:

Kindergarten

- Verbal Counting
- Counting Sets
- Naming Numbers
- Number Comparison
- Number Line (0–10)

Grade 1

- Verbal Counting
- Next Number
- Naming Numbers
- Writing Numbers
- Number Comparison
- Number Line (0–100)
- Number Facts (Addition/Subtraction)

Grade 2

- Writing Numbers
- Number Comparison
- Ordering Numbers
- Number Line (0–100 and 0–1000)
- Number Facts (Addition/Subtraction)

Grade 3

- Writing Numbers
- Ordering Numbers
- Number Comparison
- Number Line (0–1000)
- Number Facts (Addition, Subtraction, Multiplication)
- Equations

Grade 4

- Writing Numbers
- Number Line (Whole numbers and Fractions)
- Number Facts (Addition, Subtraction, Multiplication, Division)
- Calculations (Addition/Subtraction)
- Equations
- Fractions

Complementary Assessments

In Kindergarten, five subtests of the Comprehensive Test of Phonological Processing (CTOPP-2) are administered to provide additional insights into cognitive processing that may affect both literacy and numeracy development. Two subtests—Rapid Automatized Naming (RAN) and Memory for Digits—are particularly relevant to numeracy learning.

French Immersion and Multilingual Learners

All students in French Immersion follow the same screening schedule and complete the EMA@School in French, the language of instruction. The tool measures universal numeracy constructs that transfer across language contexts. Multilingual learners (MLLs) also follow the same schedule, with adjustments made in exceptional cases. School teams are encouraged to consult provincial and LRSD-specific MLL resources when interpreting results for these students.

Data Use and Equity

Screening data is collected and stored centrally. Data is analyzed via Microsoft Power BI, supporting responsive instructional planning at both school and divisional levels. The EMA@School assessments are not summative and should not be used to determine report card grades. Rather, it is intended to help teachers identify and address gaps in their students' foundational numeracy skills and fluency development. The EMA@School can also be used as the pre- to post-test measure for evaluating interventions focused on foundational numeracy skills (AIM Collective, 2024a, 2024b)

Early Numeracy Screening and Instruction in LRSD

Introduction

The Louis Riel School Division (LRSD) is committed to developing strong numeracy skills in all learners through equitable, inclusive, and evidence-based practices. In line with current research from fields such as cognitive science, psychology, and education, LRSD uses universal early numeracy screening to identify students' strengths, learning needs, and early signs of challenges that may require more targeted instruction. This report outlines the principles behind early numeracy screening, effective teaching practices, and the roles and responsibilities across the system.

This document frequently employs the term "evidence-based." This term refers to practices and tools supported by rigorous peer-reviewed research and meta-analyses that demonstrate their impact on student learning, and in the case of screening tools, their proven reliability and validity in identifying specific learning challenges.

Principles of Early Numeracy Screening

According to contemporary research, an evidence-based early numeracy screening tool is one that effectively identifies students who may have future difficulties with mathematics. Effective early numeracy screening tools are comprehensive and assess foundational numeracy skills, have good psychometric properties, and provide information that can be used by teachers to inform instruction. The Early Math Assessment @ School (EMA@School) includes tasks to assess skills in number knowledge, number relations, and number operations.

Key Components of EMA@School

Foundational early mathematical skills include knowledge of symbols, relations, and operations (B. L. Devlin et al., 2022; Jordan et al., 2010). Early symbolic knowledge includes numbers (both words and digits), mathematical vocabulary (such as behind, or half), and math-specific symbols (such as + and =). Relations includes relative magnitude (e.g., 4 < 5; 6 > 2), and ordinal relations (1 2 3 …). Operations include arithmetic and comprise both conceptual knowledge (e.g., 4 + 2 = 2 + 4; commutativity principle) and procedural skills (e.g., 4 + 2 = 6). The EMA@School includes tasks in each of these subdomains. Although skills in each subdomain are related, each predicts mathematics separately and thus can provide independent insights into children's number skill development.

Note, tasks are classified according to the major knowledge category they represent, but several tap into more than one category. The EMA@School currently does not address other areas of skill that are adjacent to mathematics or require more advanced knowledge (e.g., spatial skills, geometry), on the assumption that number skills are foundational to mathematical learning (Hawes et al., 2021). The EMA@School tasks are well known in the research literature. Select tasks measure specific foundational skills. The following is a detailed description of each of the three sections of the EMA@ School. Each section also contains some specific "Teacher Tips" for teachers to consider when working with students on the identified area.

The EMA@School screening tool is reliable and valid. Although refinements will continue as additional data are collected and analyzed, the tool has been developed using evidence-based practices and represents the only Canadian resource of its kind currently available to identify and support early indicators of math performance.

Number Knowledge

Kindergarten

The Importance of Counting

Counting is one of the earliest number skills children acquire– it requires symbolic knowledge (i.e., the number words), relational knowledge (number order) and operational knowledge (e.g., using counting to add or subtract). Some students arrive at school with extensive counting skills whereas others are unable to count successfully to 5 (Litkowski et al., 2020). Because these skills can be acquired at home or other preschool experiences, they are often referred to as "informal numeracy" (Purpura et al., 2013; Susperreguy et al., 2020) whereas those skills taught in kindergarten and beyond are referred to as "formal numeracy". Learning to count involves more than just reciting the count sequence, however. Children need to learn that the purpose of counting is to determine quantity (Gray & Reeve, 2014, 2016). To count with meaning, children need to understand three essential counting principles: a) stable order of the count words, that is knowing and using the number words in order, b) one-to-one correspondence between the items counted and the count words, that is counting each item once and only once, and c) cardinality – the last number word stated in a count indicates quantity, that is, how many items are in the set (Gallistel & Gelman, 1990; Gelman & Gallistel, 1978).

Additional Counting Principles

The remaining nonessential principles are abstraction and order irrelevance. Abstraction is recognizing that a group of objects can be counted even if they are not the same (Siegler, 2003). It allows children to realize that a set of objects (e.g., with 3 dogs and 4 cats) is also a set of 7 animals. The order irrelevance principle is that the order of counting items doesn't affect the total—the final count is always the same. Children typically develop this understanding by mid-elementary school (Kamawar et al., 2010; LeFevre et al., 2006).

Counting Milestones

Children learn the counting principles gradually from age 2 to 6 (Purpura et al., 2013). EMA@School kindergarten assessments of Verbal Counting and Dot Counting are useful for ensuring that students have the required knowledge and skills before the transition to grade 1. The Next Number task, suitable for advanced kindergarten and grade 1 students, requires that students complete a counting sequence. These sequences get progressively more complex, tapping into children's knowledge of the rules for generating higher numbers. For example, which number comes next (12 13 14 15 __ __), knowledge of other sequences (2 4 6 8 __ __), and fluency of access, allowing them to count backwards (10 9 8 7 _ _).

Symbolic Mapping and Connections

Learning is about creating connections. Math learning is cumulative and can be viewed, at least in part, as a hierarchy of connections among numerical and mathematical symbols (Hiebert, 1988). Connections between symbols and their concrete representations anchor this hierarchy, for example, knowing that the number 4 represents a quantity of ★★★★. Along with successfully connecting the digit 4 with the quantity ★★★★. However, children need to connect the verbal number word "four" with its corresponding number symbol (Hurst et al., 2017; Jiménez Lira et al., 2017). Mapping is the term used to describe connecting quantities, digits, and verbal number words. In kindergarten, students complete a **Number Naming** task where they are asked to use verbal number words to name digits.

End-of-Year Expectations

By the end of kindergarten, students are expected to have mastered the essential counting principles, and hence, understand the purpose of counting; verbally count to 30 (or higher); and name number symbols to 10 (or higher). The EMA@School assessments can be used to identify which students need extra support because they have not yet mastered these minimal standards. Such support might include pointing and counting practice (for one-to-one correspondence), digit matching games (for mapping and cardinality practice), counting songs, and other applicable activities. Because these skills are foundational for later learning, teachers can use these number knowledge assessments (**Verbal Counting, Next Number, and Number Naming**) to identify grade 1 students who are unprepared to learn grade 1 material.

Grades 1 to 4

Mapping and Language Structure Challenges

As students learn about larger numbers (i.e., 10 to 100 to 1000), they need to acquire new rules for mapping number words to number symbols. These rules reflect the structure of the number system but there can be conflict between the verbal labels and the written symbols, especially in some languages. Consider the French "quatre-vingt-dix-huit" (which translates to four-twenty-eighteen) versus saying "ninety-eight" in English, for example. Even a familiar number like eighteen is often written as 81 (an inversion error) when students are learning. In languages such as Dutch or German, where decade numbers such as 24 are named as "four-and-twenty," inversion errors are common into grade 2 (Imbo et al., 2014).

Understanding Place Value and Syntax Errors

Beyond the verbal labels and the written symbols, children need to understand that the position of a digit indicates its value. Thus, 21 is two tens and one unit, whereas 12 is one ten and two units. Each year, the range of numbers that students learn increases. By grade 2, for example, children are expected to know the number system in the hundreds. A student who hears "two-hundred five" and writes "2005" has not yet mastered the rules for transcoding spoken numbers into written digits (Skwarchuk & Anglin, 2002). This error (called a syntactic error) indicates the student does not understand how the relative positions of written numbers reflect place value, possibly because they have not learned the rules for representing larger numbers. Listening to numbers and then writing the symbols requires students to transcode between verbal and written numbers (Clayton et al., 2020; Simmons et al., 2012; Sowinski et al., 2015).

Identifying Transcoding Errors

Children with low math performance demonstrate poor understanding of place value rules in the number range they should have learned (Moura et al., 2013). The EMA@School **Writing Numbers** assessment helps teachers identify students' transcoding errors (grades 1 to 4).

Tips for Teachers - Number Writing

Students in grades 1 and 2 are expected to know numbers to 100; students in grade 3 and 4 are expected to know numbers to 1000 and 10 000 respectively. Many children exceed these benchmarks, but some lag behind (Litkowski et al., 2020).

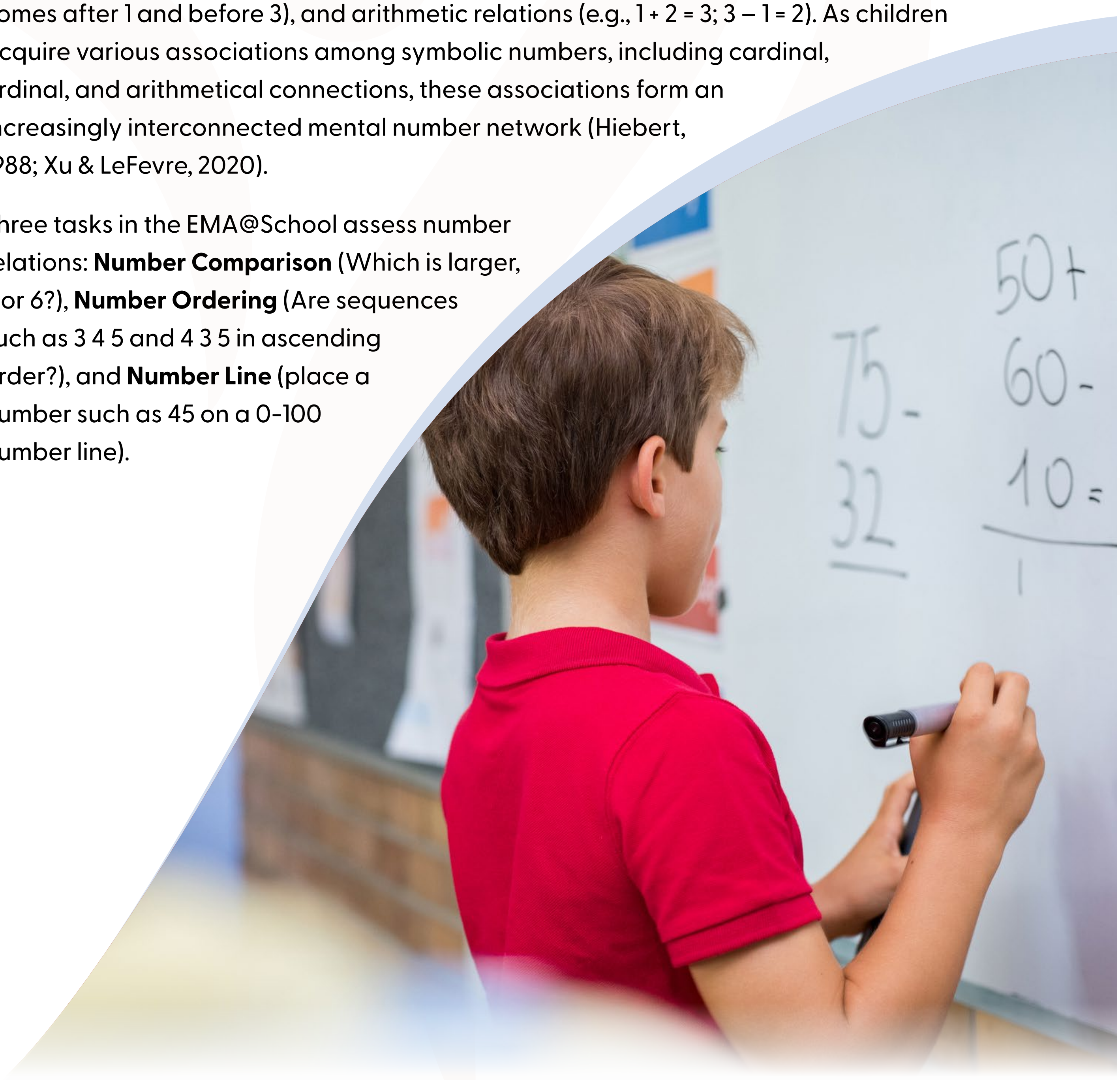
Teachers can use the Number Writing task to identify the kinds of mistakes their students make and identify which rules are not yet mastered. Specifically, teachers can identify gaps in children's knowledge of larger numbers (e.g., place value issues; writing two hundred five as 2005 or reversing number order; 28 versus 82, etc.). In response, teachers can customize number writing supports as needed, using number matching games, place-value charts, and other activities that highlight the patterns and rules that determine number structure.

Number Relations

Understanding Number Relationships

Numbers can be related to each other in many ways. Consider the numbers 1, 2, and 3. These numbers have cardinal (quantity/magnitude) relations (e.g., 3 > 1; 2 < 3), ordinal relations (e.g., 2 comes after 1 and before 3), and arithmetic relations (e.g., 1 + 2 = 3; 3 – 1 = 2). As children acquire various associations among symbolic numbers, including cardinal, ordinal, and arithmetical connections, these associations form an increasingly interconnected mental number network (Hiebert, 1988; Xu & LeFevre, 2020).

Three tasks in the EMA@School assess number relations: **Number Comparison** (Which is larger, 3 or 6?), **Number Ordering** (Are sequences such as 3 4 5 and 4 3 5 in ascending order?), and **Number Line** (place a number such as 45 on a 0-100 number line).



Kindergarten to Grade 3

Number Comparison

Quick and accurate access to quantities from symbolic numbers supports the development of other number skills like ordinal knowledge, arithmetic, and fractions. **Number Comparison** is a timed number comparison task where students quickly and accurately cross off the numerically larger digit in a pair. Number Comparison is used from kindergarten to grade 3, with appropriate modifications in timing.

Number Comparison combines knowledge of how symbols are connected to quantities with the ability to compare those quantities mentally. Using a number comparison screener has shown that number comparison is a foundational mathematical skill (Hawes et al., 2019; Nosworthy et al., 2013). Moreover, number comparison can be used to identify children with persistent developmental dyscalculia (Bugden et al., 2021).

Tips for Teachers - Number Comparison

Students in kindergarten and grade 1 with the weakest number comparison skills lack automatic/direct associations between the digit symbols and quantities. For these students, teachers can focus on activities that support linking digits and quantities such as card games like War, board games like Sorry, or dice games – or other activities where students practice linking visual symbols with quantities (Gasteiger & Moeller, 2021).

Grades 2 and 3

Number Ordering

As children's number relations become more sophisticated and integrated, they are able to use ordinal skills (e.g., what number comes after 4?) on increasingly complex ordering tasks (e.g., is the sequence 2 4 5 in ascending order?) (Lyons et al., 2014; Xu & LeFevre, 2021). **Number Order** is included in the EMA@School for students in grades 2 and 3. Some students in grade 1 can do the Number Order task, however, like children in kindergarten, many find it difficult to understand that nonadjacent numbers such as 2 4 6 are nevertheless 'in order' (Hutchison et al., 2022).

Knowledge of the sequential relations amongst numbers is distinct from knowledge about quantity (Lyons & Ansari, 2015; Lyons & Beilock, 2013). **Number Order** is a timed task where students quickly and accurately judge if three numbers are in increasing order (e.g., 2 3 5 vs. 3 1 2). In grades 2 and 3, students' fast and accurate access to number sequences captures the developing mental framework for number relations that supports calculation skills (Lyons et al., 2014; Sasanguie et al., 2017; Sasanguie & Vos, 2018).

Tips for Teachers - Number Order

For students with weak order judgment skills, teachers can help students develop and use number ordering relations in various contexts such as games involving sequences – ordering numbers, what comes before, what comes next, and so on. Flexibility in using both order and magnitude knowledge to determine if sequences are ordered develops further beyond grade 3 (Lyons et al., 2014).

Grades 1 to 4

Number Line Estimation

Estimating the position of a number in the Number Line captures two aspects of a student's mathematical knowledge. First, it measures their understanding of the ordinal relations among numbers (i.e., 3 comes after 2 and before 4; 50 comes after 40 and before 60). Second, number line estimation requires proportional reasoning skills. Proportional reasoning is used to place the number accurately on the line (e.g., 49 is close to 50 and 50 is one-half of 100 so an appropriate strategy is to divide the line in half).

In the EMA@School, Number Line is used to assess students' developmentally appropriate understanding of ordinal and proportional relations amongst numbers. For kindergarten students, the number range is 0-10, for students in grade 1, the range is 0-100, students in grade 2 are asked about both 0-100 and 0-1000 number line, for students in grade 3, the number range is 0-1000 and in grade 4, students see both whole number and fraction number lines. Students with estimation errors greater than 20% (i.e., placing 7 either below 5 or above 9 on a 0-10 number line; placing all numbers above 100 near to 1000) have a poor understanding of the tested number range. Number line performance is a sensitive index of developing mathematical knowledge (Booth & Siegler, 2006), in part because the task is novel to many students, requiring them to invent a strategy.

Tips for Teachers - Number Line

Teachers can support students' understanding of how number magnitudes and number line locations are connected with activities that promote understanding of ordinal relations, both for younger students (e.g., What comes before, what comes next) (Xu & LeFevre, 2016), linear board games (Siegler & Ramani, 2009) and, for older students, with proportional reasoning tasks (e.g., mark the middle of the number line, identify the middle number). Number lines are useful teaching tools and provide a concrete representation for learning about fractions and decimals.

Number Operations

The Relationship Between Fluency and Conceptual Understanding

Procedural fluency and conceptual knowledge of arithmetic principles are mutually reinforcing (Rittle-Johnson & Alibali, 1999). Both types of knowledge are central to the development of strong mathematical skills (Crooks & Alibali, 2014; Fyfe et al., 2012). Thus, children's acquisition of the basic number operations are foundational predictors of later fraction and algebra skills (Schneider et al., 2017). The EMA@School includes Number Facts and Calculation, which are measures of procedural fluency and Equations, a measure of conceptual knowledge.

Defining Arithmetic Fluency

Arithmetic fluency reflects how quickly and efficiently students can retrieve number facts or apply efficient strategies. Built on knowledge of cardinal and ordinal associations, fluency skills scaffold higher level mathematical competence. Importantly, arithmetic fluency is a core ability and is closely related to many other mathematical skills (Price et al., 2013), including problem solving (Lin, 2020). Students who know their number facts have more working memory available to strategize and focus on the problem they are solving compared to students who need to laboriously calculate the arithmetic. Importantly, fast and accurate fact retrieval indicates mastery of foundational arithmetic skills and mastery is a more sensitive metric than accuracy when it comes to monitoring growth in student skill (VanDerHeyden & Peltier, 2023; VanDerHeyden & Solomon, 2023).

Grades 1 to 4

Number Facts

Number Facts assessments include single digit addition and subtraction (all grades), multiplication (grade 3) and combined multiplication and division (grade 4).

Tips for Teachers - Number Facts

The Number Facts assessment will identify students with weak arithmetic fluency (addition, subtraction, multiplication, division). Performance on Number Facts can be used by teachers to gauge the current arithmetic skills of their group of students and plan lessons accordingly. Teachers can support fact fluency with card or board games (e.g., cribbage), classroom practice, and other applicable activities (Gasteiger & Moeller, 2021). Access to online, gamified practice supports students' fluency, but there are many other ways to encourage mastery of number facts. Building skills can also reduce anxiety as students realize that they can be successful (Codding et al., 2023).

Grades 3 and 4

Calculation

Calculation includes multi-digit addition and subtraction and is a measure of students' computation skills and their understanding of place value. To solve these problems, students need to manipulate the numbers. They can use standard algorithms or other strategies such as breaking the number down (e.g., 83 + 27 = [7 + 3] and [80 + 20] = 110). As students' number skills develop, their solution strategies become more efficient (Hickendorff et al., 2019). To quickly and efficiently solve calculation problems that involve regrouping, students need to process place value information. Students who experience math difficulties take more time and make more errors when solving multi-digit arithmetic problems (Lambert & Moeller, 2019).

Equations: Conceptual Knowledge of Arithmetic Principles

Equations assesses students' knowledge of five arithmetic principles. These include the following basic principles:

- **Identity** – Adding or subtracting zero, or multiplying or dividing by 1 does not change the number.
- **Negation** – subtracting a number from itself equals 0 or dividing it by itself equal

1 (Robinson, 2017).

- **Inversion** – The principle of Inversion arises from an understanding of identity and negation, such that students can easily solve problems like 3 + 54 – 54 and 21 x 5 ÷ 5 without calculating (Crooks & Alibali, 2014; Robinson & LeFevre, 2011).

The following two principles allow students to flexibly evaluate equations presented in a variety of formats:

- **Commutativity** – This is the principle that the order of operands in addition doesn't matter, so that 3 + 4 will have the same answer as 4 + 3. Students implicitly understand this principle when they know they can solve both 2 + 5 and 5 + 2 by counting on from 5 (Siegler & Braithwaite, 2017). Multiplication is also commutative, and that understanding can be used to simplify learning the answers to multiplication facts. There are half as many facts to learn when students are taught the "small x large" facts and the commutativity rule (Campbell & Xue, 2001; LeFevre & Liu, 1997).
- **Equivalence** – This is the rule that the information on both sides of an equation must be equal. Equivalence is signalled by the equal sign, and it is fundamental for learning algebra (Crooks & Alibali, 2014; Star & Rittle-Johnson, 2008).

Knowledge of equivalence starts out very simply, for example, knowing that 4 = 4 is a valid equation. At first, students may think that the equal sign in a problem like 3 + 2 = ___ means something like "add these two numbers and put the answer in the blank space." That operational notion must be replaced by a relational understanding – the equal sign really means "the quantity on the left side and the quantity on the right side should be the same". This relational understanding is critical but does not fully develop until grade 6 or later in many countries (Simsek et al., 2021). Students who acquire relational understanding earlier and therefore develop flexible problem-solving skills will find learning about decimals, fractions, and algebra easier (Crooks & Alibali, 2014; McNeil et al., 2006; Prather & Alibali, 2009).

Tips for Teachers - Equations

The Equations task provides information about which principles are familiar to students. Helping students to learn these principles and become flexible problem solvers will prepare them for learning about fractions and algebra in later grades (Robinson & Dubé, 2012). Providing frequent opportunities for students to see equations in many different forms and fostering a relational interpretation of the equal sign will support student progress.

Fraction Concepts

The Importance of Fraction Understanding

Whole number knowledge forms the foundation for building strong fraction skills. Fraction skills predict students' later understanding of algebra, and their overall math achievement in high school (Booth & Newton, 2012; Jordan et al., 2017; Siegler et al., 2013). Helping students develop strong fraction skills prepares them for later mathematical success.

The **Fraction Concepts** task measures student's' understanding of how fraction symbols connect to fraction magnitudes, that is, how fraction symbols are related to the quantities they represent. The magnitude of a fraction is based on the relation between the numerator and denominator (i.e., 3/8< 1/2 even though 3 > 1 and 8 > 2). Whole number knowledge can make it difficult for students to grasp how fraction symbols represent magnitude. Those students who are less skilled will show evidence of this 'whole number bias' (Braithwaite & Siegler, 2023; Siegler & Braithwaite, 2017). The questions on the **Fraction Concepts** task tap into three foundational fraction concepts: representation, equivalence, and magnitude.

1. **Representations**

   Fractions can be represented in multiple ways. For example, 3/8 can represent:
   - a discrete quantity (3 out of 8 students);
   - part of a whole (3 slices of an 8-slice pizza); or
   - a continuous quantity (3/8 of a litre).

2. **Equivalence**

   Unlike whole numbers, fractions with different integers can describe the same magnitude (e.g., 3/8 = 6/16).

3. **Magnitude**

   The magnitude of a fraction is based on the relationship between the numerator and denominator. For example, 3/8 < 1/2 even though 3 > 1 and 8 > 2.

Tips for Teachers

The following common student mistakes provide information about gaps in their understanding. Teachers can address these misconceptions directly and help students develop strong conceptual knowledge about fractions (Deringöl, 2019).

Common Fraction Errors

1. **Confusing the numerator and the denominator**

   When representing fractions, students may misunderstand what the numerator and denominator represent. For example, a student may incorrectly identify 3 out of 8 slices of pizza as 3/11, 3/5 or 5/8.

2. **Applying Whole Number Logic to Fractions**

   Students may not understand that the magnitude of the fraction is based on the relation between the numerator and denominator. Instead, they may rely on their understanding of whole numbers to compare fractions, which leads to predictable errors:

   - Assuming that a larger denominator indicates a larger fraction (e.g., thinking 1/3 is greater than 1/2).
   - Assuming a larger numerator indicates a larger fraction (e.g., thinking 5/8 is greater than 2/3).
   - Judging the size based on the gap between the numerator and denominator (e.g. thinking 2/3 is greater than 7/9) (Rinne et al., 2017).

The Comprehensive Test of Phonological Processing (CTOPP-2)

Overview

In partnership with researchers from the University of Toronto's Ontario Institute for Studies in Education (OISE), the Louis Riel School Division (LRSD) selected the **CTOPP-2** for its strong reliability and validity as a phonological processing screener. **It is used to identify early risk factors that may impact literacy and numeracy development.**

Subtests Administered in Kindergarten

Five CTOPP-2 subtests are administered in Kindergarten. Three of these are directly related to phonological awareness. Two others—**Rapid Automatized Naming (RAN)** using colours and digits, and **Memory for Digits**—have implications for both **literacy** and **numeracy**.

- **RAN** measures fluency and automaticity—skills linked to reading and math success. Students who score at risk may need more time, repetition, and supports that reduce cognitive load across academic tasks.
- **Memory for Digits** measures recall and working memory. Low scores may reflect challenges with either memory or focus, and the appropriate response depends on which is more likely.

Scoring and Follow-Up

Subtest scores for the CTOPP-2 are classified as follows:

- **Above 26th percentile** – At or above benchmark
- **17th–26th percentile** – At benchmark; monitor progress
- **16th percentile or lower** – At risk; follow up with observation and possible further assessment
- **Score of 999** – Test not completed or more than four errors (common in students with limited English, non-speaking status, or developmental disabilities)

School teams should document and explain 999 scores clearly. For students with limited English, refer to divisional Multilingual Learner (MLL) supports. For students with diagnosed needs, consult with clinical team members to guide programming.

Using the Data

CTOPP-2 results should be reviewed collaboratively by school teams—including administration, classroom teachers, student services staff, and clinicians. A **Student Services Team Meeting (SSTM)** is potentially a good opportunity to discuss results as a team and develop next steps in programming and support.

Practices for Early Screening

The EMA@School is designed to identify student learning strengths, specific needs, and risk for learning challenges related to numeracy. It is not intended to be a summative assessment or used for report card grading, nor is it diagnostic.

The EMA@School combined with results from the CTOPP-2, Kindergarten Parent Questionnaire responses, other classroom assessments, and classroom observations can be used by teachers to identify which students may need extra support and in which subskills. Teachers can use the tasks in the EMA@School to identify the kinds of mistakes students make and identify which concepts are not yet mastered. For example, teachers can gauge the current arithmetic skills of their group and plan lessons accordingly. The EMA@School provides additional information from each measure that teachers can use to better understand individual students' strengths and limitations.

Language plays a significant and foundational role in the development of numeracy in early learners, especially when considering different linguistic structures. Teachers and parents use words to communicate mathematical ideas (LeFevre et al., 2010; Purpura & Ganley, 2014; Xu et al., 2021), and a child's general vocabulary, along with math-specific terms like "sum" or "greater than," predicts their mathematical achievement (Hornburg et al., 2018). Early knowledge of spatial and quantity words, such as "more" or "less," is also predictive of success in tasks like verbal counting and number identification (Hornburg et al., 2018).

A key aspect where language impacts numeracy is in the mapping of number words to number symbols. As students advance to larger numbers, they must learn new rules for this mapping, which reflect the structure of the number system. However, there can be a conflict between the verbal labels and the written symbols, particularly in certain languages (Clayton et al., 2020; Simmons et al., 2012; Sowinski et al., 2015). Related challenges can be identified through assessments like the Number Writing task, allowing teachers to address gaps in knowledge of larger numbers and place value.

Numeracy Screening in French Immersion

Students enrolled in French Immersion (FI) follow the same screening schedule and participate in the same EMA@School assessments as their peers in the English program. These assessments are administered in French, consistent with the language of numeracy instruction in FI at all grade levels.

The EMA@School measures foundational numeracy skills and is designed to assess universal competencies—such as symbol knowledge, number relations, and number operations—that transfer across language contexts. Research indicates that mathematical reasoning and fluency are not language-dependent in the same way as literacy. Furthermore, specific benchmarks for FI and English program have been established to ensure that language considerations are built into the scoring.

Teachers and school teams supporting FI program students are encouraged to use screening results to inform planning and ensure that students who demonstrate risk receive appropriate support that is aligned with LRSD's inclusive and proactive approach to learning.

Numeracy Screening for Multilingual Learners

Multilingual learners (MLLs) should also participate in EMA@School numeracy screening on the same schedule as their peers. The EMA@School is designed to assess fluency and conceptual understanding of mathematical ideas rather than language-based comprehension. As such, it provides a valid and meaningful indicator of numeracy development for MLLs.

In exceptional circumstances, school teams—under the direction of the principal and in consultation with teachers—may decide to adjust the timing of screening administration if it is in the best interest of the student (e.g., a student new to Canada who is experiencing trauma or distress when working one-on-one with unfamiliar adults). In such cases, a student may be exempted from one screening period and reassessed for participation in the following period.

When interpreting screening results for multilingual learners, teams should take into account factors such as language exposure, cultural background, and learning history. Screening should be viewed as one data point within a broader understanding of the student's development.

To support programming for MLLs, schools should refer to:

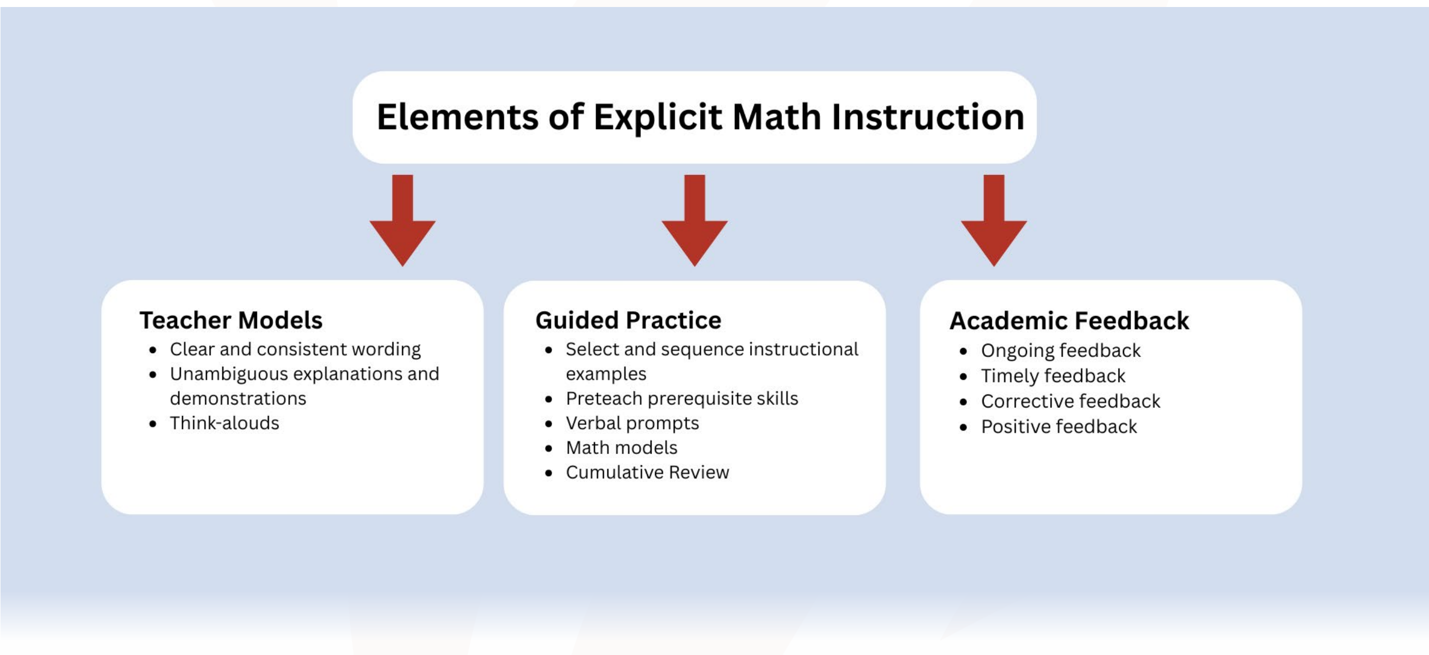
- The Manitoba Education EAL Intake Process for Early Years & Middle Years
- The Manitoba Kindergarten to Grade 12 Curriculum Framework for English as an Additional Language (EAL) and Literacy, Academics, Language (LAL), which includes learner stages and assessment guidelines)

Additional LRSD-created resources to support multilingual learners are available on the Teaching and Learning Portal under EAL on the LRSD website.

Optimizing Class time for a Comprehensive Approach to Early Numeracy Instruction

Introduction

An engaging, relevant, and developmentally appropriate numeracy learning experience starts with a student's ability to understand and manipulate numbers.



(Doabler & Fien, 2013)

Although its meaning varies in the research literature (Gersten et al., 2009), most would agree that explicit math instruction involves a series of teaching behaviors that include:

- the teacher modeling a new concept or skill,
- the teacher providing guided practice opportunities,
- the teacher checking for student understanding,
- the teacher providing academic feedback, and
- the students engaging in independent practice.

Systematic and explicit instruction in numeracy development strategies is essential in the early years program. Resources should be aligned with the best practices identified by research. The consistent application of a variety of multimodal teaching strategies is integral to the classroom routine. While these elements alone do not constitute a comprehensive approach to mathematics instruction, they are the foundational underpinnings of a robust numeracy program.

Classroom time can be effectively used by providing instruction that is guided by the principles of Differentiated Instruction and Universal Design for Learning that are informed by students' learning strengths, growth, and needs including:

- Predictable schedules and classroom routines to support students in knowing when the focused time for math instruction takes place during the day;
- Lessons that follow developmental learning needs in the language of instruction, progressing from simple to more complex skills and abilities;
- Systematic and explicit instruction of targeted foundational numeracy skills;
- Multiple opportunities for small-group instruction and teacher feedback;
- Independent practice for students who can practice the skill correctly;
- Authentic numeracy learning experiences for all students; and
- Supporting student engagement in tasks by providing timely descriptive feedback as appropriate.

Additionally, the development of mathematical skills and understanding is often enhanced by intentional connections to other subject areas. It is important to recognize that the integration of meaningful, real-world numeracy experiences can deepen conceptual understanding and strengthen the development of knowledge and skills across the curriculum.

An engaging, relevant, and developmentally appropriate numeracy learning experience starts with a student's ability to make sense of numbers and mathematical relationships. To foster this confidence and competence in all learners, LRSD endorses a systematic, explicit, and multimodal approach to mathematics instruction, supported by data from screenings, observations, and other sources. Teaching emphasizes key foundational components of effective early numeracy instruction:

- **Conceptual Understanding** – comprehension of mathematical concepts, operations, and relationships
- **Procedural Fluency** – skill in carrying out procedures flexibly, accurately, efficiently, and appropriately
- **Strategic Competence** – the ability to formulate, represent, and solve mathematical problems
- **Adaptive Reasoning** – the capacity for logical thought, reflection, explanation,

and justification
- **Productive Disposition** – a habitual inclination to see mathematics as sensible, useful, and worthwhile, coupled with a belief in one's own efficacy.

This forms the foundation of LRSD's vision for numeracy programming in the context of the Manitoba Provincial Mathematics Curriculum.

Building from this strong foundation, LRSD educators develop a comprehensive approach to numeracy instruction that also includes additional key elements. This includes:

- using high-quality mathematical tasks to help students develop a sense of mathematical structure and reasoning;
- prioritizing explicit and informal opportunities to build mathematical vocabulary and reasoning across all subjects;
- providing students with daily, authentic opportunities to engage in mathematical dialogue, pose and solve problems, and represent their thinking in multiple ways.

This approach enables students to fully develop their critical thinking, reasoning, and communication skills in mathematics.

RTI and MTSS Approaches to Numeracy

LRSD strongly advocates for the application of the principles of Response to Intervention (RTI) and Multi-Tiered System of Supports (MTSS) to guide all intervention planning, ensuring all students, including those with numeracy learning difficulties or disabilities, receive high-quality instruction and targeted support.

RTI is a proactive, data-driven framework that helps teachers make informed decisions and adjust instruction to improve student learning. It follows a three-tier model:

- Tier 1: Research-supported teaching practices in regular classrooms.
- Tier 2: Targeted support for students needing additional assistance.
- Tier 3: Intensive, individualized interventions for students who continue to struggle.

MTSS builds on RTI by incorporating a tiered approach that addresses not only academic needs but also social, emotional, and behavioral development. All interventions should be evidence-based or aligned with known, effective classroom instruction methods to maximize student success.

Applying the Data in Lesson and Intervention Planning

Data from early screenings can help teachers plan instruction that responds to student strengths and needs, with a focus on supporting those who score below benchmarks. Below are some common patterns that may appear in EMA@School data. These results should always be interpreted alongside teacher observations and supplemented, when necessary, with additional classroom-based assessments.

- Identifying students who have not yet mastered minimal standards in counting or mapping indicates a need for extra support, including hands-on counting and/or subitizing practice.
- Recognizing challenges with number comparison skills suggests a need to focus on linking digits and quantities.
- Weak order judgment skills indicate a need to develop number ordering relations.
- Estimation errors on the number line suggest a need for support with ordinal relations and proportional reasoning.
- Weak arithmetic fluency points to a need for targeted practice.
- Errors in calculation or fractions highlight specific misconceptions or lack of understanding in place value or fraction concepts.

This use of screening data to identify specific needs and target instruction aligns with the principles of a tiered approach, where students receive support matched to their level of need. The assessment helps teachers identify students who would benefit from additional support beyond universal classroom instruction. Teachers can then draw on recommended activities and strategies to address those specific gaps. Support and intervention resources as well as lesson ideas can be found on the LRSD Numeracy Portal.

Roles and Responsibilities

Louis Riel School Division

LRSD will be responsible for:

- establishing processes and practices for students in kindergarten to grade 4 to be screened for early numeracy, using an evidence-based screening tool. The tool currently provided by the division is the EMA@School;
- establishing processes and practices that protect student privacy throughout the screening process in accordance with applicable privacy legislation;
- the collection of early numeracy screening data and making it accessible to school administrators and where appropriate, teaching and clinical staff;
- providing a template for reporting results to parents (in development);
- developing common language for schools to use in communications to parents/guardians regarding the purpose of early numeracy screening, implementation details, and individual screening results; and
- providing opportunities for relevant school and school division staff to have necessary training on the use of early numeracy screening, including how to collect, record, and interpret screening data to inform programming.

School Principals & Vice Principals

School principals support the implementation of the screening measures at the school-level and support student development of numeracy by:

- putting in place processes and practices at the school level:
  - for students in kindergarten (English and FI program) and grade 1 (FI program) to be screened using the CTOPP-2;
  - for students in kindergarten to grade 4 to be screened using the EMA@School (both English and FI programs in the language of instruction);
- reviewing the EMA@School data with classroom teachers and assigning student services teachers to establish next steps to support planning for response to intervention;
- supporting communications with parents/guardians to encourage collaboration

between the home and school;
- preparing classroom timetables for kindergarten to grade 4 that allocate focused time for numeracy instruction, including uninterrupted time for systematic and explicit instruction in foundational numeracy skill development within a daily common block;
- encouraging ongoing professional learning in systematic and explicit instruction in foundational numeracy, as well as being committed to their own early numeracy instructional leadership, to prepare educators and other professionals to support classroom implementation.

Classroom Teachers

Under the leadership of their principals, teachers support student development of numeracy skills by:

- administering early numeracy screening in alignment with divisional expectations;
- implementing evidence-based instructional practices that are systematic and explicit; and
- communicating regularly and meaningfully with parents/guardians to share early numeracy screening results and provide updates on their child's numeracy development.

Student Services Teachers

Working collaboratively with classroom teachers, school administrators and school clinicians, student services teachers play a key role in supporting numeracy instruction by:

- supporting classroom teachers with the interpretation of testing results;
- supporting the classroom teachers with the implementation of evidence-based instructional practices; and
- supporting classroom teachers in developing and implementing intervention plans for students identified as at risk through screening results.

Recording and Reporting Requirements

Divisional Data Collection

LRSD collects early screening data centrally to track student participation and results each academic year. This centralized data collection supports both school-level and divisional planning by providing valuable insights into student needs and trends over time.

Data Management

LRSD collects screening data, along with responses from the Kindergarten Parent/Guardian Questionnaire, through its Student Information System (SIS) and the PowerSchool Parent Portal. This information is compiled into reports using Microsoft Power BI and is accessible to school and divisional administrators, clinicians, and teachers.

Early Math Assessment (EMA) Schedule

	Kindergarten	Grades 1–4
Before School Year	***Kindergarten Questionanaire***	
Sept.		
Oct.	Optional EMA	Optional EMA
Nov.	Report Cards Due	Report Cards Due
Dec.		
Jan.	Mandatory EMA	Mandatory EMA
Feb.		
Mar.	Report Cards Due	Report Cards Due
April		
May	Mandatory EMA	Mandatory EMA
June	Report Cards Due	Report Cards Due

NOTES:

1. **Unmarked times indicate potential intervention periods.**
2. **K-1 Release Time for January and May Testing (not available for October):**
   - **Kindergarten:** one full day per class (≈10 minutes per student)
   - **Grade 1:** one half-day per class (≈6 minutes per student)
   - **Grade 1/2 multiage classes:** Schools should share release time proportionally based on Grade 1 enrollment in each class.

All assessments must be administered in the language of instruction.

Exception: French Immersion Kindergarten teachers may use the English version for the optional October test if they prefer. Otherwise, all tests must be administered in the language of instruction.

References

Booth, J. L., & Newton, K. J. (2012). Fractions: Could they really be the gatekeeper's doorman? https://doi.org/10.1016/j.cedpsych.2012.07.001

Booth, J. L., & Siegler, R. S. (2006). Developmental and individual differences in pure numerical estimation. Developmental Psychology, 42(1), 189–201. https://doi.org/10.1037/0012-1649.41.6.189

Bugden, S., Peters, L., Nosworthy, N., Archibald, L., & Ansari, D. (2021). Identifying Children with Persistent Developmental Dyscalculia from a 2-min Test of Symbolic and Nonsymbolic Numerical Magnitude Processing. Mind, Brain, and Education, 15(1), 88–102. https://doi.org/10.1111/mbe.12268

Campbell, J. I. D., & Xue, Q. (2001). Cognitive arithmetic across cultures. Journal of Experimental Psychology: General, 130(2), 299–315. https://doi.org/10.1037/0096-3445.130.2.299

Clayton, F. J., Copper, C., Steiner, A. F., Banfi, C., Finke, S., Landerl, K., & Göbel, S. M. (2020). Two-digit number writing and arithmetic in Year 1 children: Does number word inversion matter? Cognitive Development, 56(April), 1–14. https://doi.org/10.1016/j.cogdev.2020.100967

Codding, R. S., Goodridge, A. E., Hill, E., Kromminga, K. R., Chehayeb, R., Volpe, R. J., & Scheman, N. (2023). Meta-analysis of skill-based and therapeutic interventions to address math anxiety. Journal of School Psychology, 100(August), 101229. https://doi.org/10.1016/j.jsp.2023.101229

Crooks, N. M., & Alibali, M. W. (2014). Defining and measuring conceptual knowledge in mathematics. Developmental Review, 34(4), 344–377. https://doi.org/10.1016/j.dr.2014.10.001

Deringöl, Y. (2019). Misconceptions of primary school students about the subject of fractions. International Journal of Evaluation and Research in Education (IJERE), 8(1), 29–38. https://doi.org/10.11591/ijere.v8.i1.pp29-38

Doabler, C. T & Fien, H. (2013). Explicit mathematics instruction: What teachers can do for teaching students with mathematics difficulties. Intervention in School and Clinic, 48(5), 276-285. DOI: 10.1177/1053451212473151

Fyfe, E. R., Rittle-Johnson, B., & DeCaro, M. S. (2012). The effects of feedback during exploratory mathematics problem solving: Prior knowledge matters. Journal of Educational Psychology, 104(4), 1094–1108. https://doi.org/10.1037/a0028389

Gallistel, C. R., & Gelman, R. (1990). The what and how of counting. Cognition, 34(2), 197–199. https://doi.org/10.1016/0010-0277(90)90043-J

Gasteiger, H., & Moeller, K. (2021). Fostering early numerical competencies by playing conventional board games. Journal of Experimental Child Psychology, 204, 105060. https://doi.org/10.1016/j.jecp.2020.105060

Gelman, R., & Gallistel, C. R. (1978). The Child's Understanding of Number. In The Child's Understanding of Number. Harvard University Press. https://doi.org/10.4159/9780674037533

Gersten, R. M., National Center for Education Evaluation and Regional Assistance, & What Works Clearinghouse. (2009). Assisting students struggling with mathematics response to intervention (RtI) for elementary and middle schools. U.S. Dept. of Education, National Center for Education Evaluation and Regional Assistance, Institute of Education Sciences.

Gray, S. A., & Reeve, R. A. (2014). Preschoolers' dot enumeration abilities are markers of their arithmetic competence. PloS One, 9(4), e94428. https://doi.org/10.1371/journal.pone.0094428

Gray, S. A., & Reeve, R. A. (2016). Number-specific and general cognitive markers of preschoolers' math ability profiles. Journal of Experimental Child Psychology, 147, 1–21. https://doi.org/10.1016/j.jecp.2016.02.004

Hawes, Z., Nosworthy, N., Archibald, L., & Ansari, D. (2019). Kindergarten children's symbolic number comparison skills predict 1st grade mathematics achievement: Evidence from a two-minute paper-and-pencil test. Learning and Instruction, 59(January 2018), 21–33. https://doi.org/10.1016/j.learninstruc.2018.09.004

References

Hickendorff, M., Torbeyns, J., Verschaffel, L., Haase, V. G., Räsänen, P., & Fritz, A. (2019). Multi-digit Addition, Subtraction, Multiplication, and Division Strategies. In International Handbook of Mathematical Learning Difficulties (pp. 543–560). Springer International Publishing. https://doi.org/10.1007/978-3-319-97148-3_32

Hiebert, J. (1988). Conceptual and procedural knowledge: The case of mathematics. Erlbaum.

Hornburg, C. B., Schmitt, S. A., & Purpura, D. J. (2018). Relations between preschoolers' mathematical language understanding and specific numeracy skills. Journal of Experimental Child Psychology, 176, 84–100. https://doi.org/10.1016/j.jecp.2018.07.005

Hurst, M. A., Anderson, U., & Cordes, S. (2017). Mapping among number words, numerals, and nonsymbolic quantities in preschoolers. Journal of Cognition and Development, 18(1), 41–62. https://doi.org/10.1080/15248372.2016.1228653

Hutchison, J. E., Ansari, D., Zheng, S., De Jesus, S., & Lyons, I. M. (2022). Extending ideas of numerical order beyond the count-list from kindergarten to first grade. https://doi.org/10.1016/j.cognition.2022.105019

Jordan, N. C., Resnick, I., Rodrigues, J., Hansen, N., & Dyson, N. (2017). Delaware longitudinal study of fraction learning: Implications for helping children with mathematics difficulties. Journal of Learning Disabilities, 50(6), 621–630. https://doi.org/10.1177/0022219416662033

Jiménez Lira, C., Carver, M., Douglas, H., & LeFevre, J.-A. (2017). The integration of symbolic and non-symbolic representations of exact quantity in preschool children. Cognition, 166, 382–397. https://doi.org/10.1016/j.cognition.2017.05.033

Kamawar, D., LeFevre, J.-A., Bisanz, J., Fast, L., Skwarchuk, S.-L., Smith-Chant, B., & Penner-Wilger, M. (2010). Knowledge of counting principles: How relevant is order irrelevance? Journal of Experimental Child Psychology, 105(1–2), 138–145. https://doi.org/10.1016/j.jecp.2009.08.004

References

Kilpatrick, J., Swafford, J., & Findell, B. (Eds.). (2001). Adding it up: Helping children learn mathematics. National Academies Press.

Lambert, K., & Moeller, K. (2019). Place-value computation in children with mathematics difficulties. Journal of Experimental Child Psychology, 178, 214–225. https://doi.org/10.1016/j.jecp.2018.09.008

LeFevre, J.-A., & Liu, J. (1997). The role of experience in numerical skill: Multiplication performance in adults from Canada and China. Mathematical Cognition, 3(1), 31–62. https://doi.org/10.1080/135467997387470

LeFevre, J.-A., Smith-Chant, B. L., Fast, L., Skwarchuk, S.-L., Sargla, E., Arnup, J. S., Penner-Wilger, M., Bisanz, J., & Kamawar, D. (2006). What counts as knowing? The development of conceptual and procedural knowledge of counting from kindergarten through Grade 2. Journal of Experimental Child Psychology, 93(4), 285–303. https://doi.org/10.1016/j.jecp.2005.11.002

LeFevre, J.-A., Smith-Chant, B. L., Fast, L., Skwarchuk, S.-L., Bisanz, J., Kamawar, D., & Penner-Wilger, M. (2010). Pathways to mathematics: Longitudinal predictors of performance. Child Development, 81(6), 1753–1767.

Lin, X. (2020). Investigating the unique predictors of word-problem solving using meta-analytic structural equation modeling. Educational Psychology Review. https://doi.org/10.1007/s10648-20-09554-w

Litkowski, E. C., Duncan, R. J., Logan, J. A. R., & Purpura, D. J. (2020). When do preschoolers learn specific mathematics skills? Mapping the development of early numeracy knowledge. Journal of Experimental Child Psychology, 195, 104846. https://doi.org/10.1016/j.jecp.2020.104846

Lyons, I. M., & Ansari, D. (2015). Foundations of children's numerical and mathematical skills. In Advances in child development and behavior (1st ed., Vol. 48, pp. 93–116). Elsevier Inc. https://doi.org/10.1016/bs.acdb.2014.11.003

Lyons, I. M., & Beilock, S. L. (2013). Ordinality and the nature of symbolic numbers. Journal of Neuroscience, 33(43), 17052–17061. https://doi.org/10.1523/JNEUROSCI.1775-13.2013

Lyons, I. M., Price, G. R., Vaessen, A., Blomert, L., & Ansari, D. (2014). Numerical predictors of arithmetic success in grades 1-6. Developmental Science, 17(5), 714–726. https://doi.org/10.1111/desc.12152

McNeil, N. M., Grandau, L., Knuth, E. J., Alibali, M. W., Stephens, A. C., Hattikudur, S., & Krill, D. E. (2006). Middle-school students' understanding of the equal sign: The books they read can't help. Cognition and Instruction, 24(3), 367–385. https://doi.org/10.1207/s1532690xci2403_3

Moura, R., Wood, G., Pinheiro-Chagas, P., Lonnemann, J., Krinzinger, H., Willmes, K., & Haase, V. G. (2013). Transcoding abilities in typical and atypical mathematics achievers: The role of working memory and procedural and lexical competencies. Journal of Experimental Child Psychology, 116(3), 707–727. https://doi.org/10.1016/j.jecp.2013.07.008

Nosworthy, N., Bugden, S., Archibald, L., Evans, B., & Ansari, D. (2013). A Two-Minute Paper-and- Pencil Test of Symbolic and Nonsymbolic Numerical Magnitude Processing Explains Variability in Primary School Children's Arithmetic Competence. PLoS ONE, 8(7). https://doi.org/10.1371/journal.pone.0067918

Price, G. R., Mazzocco, M. M. M., & Ansari, D. (2013). Why mental arithmetic counts: Brain activation during single digit arithmetic predicts high school math scores. Journal of Neuroscience, 33(1), 156–163. https://doi.org/10.1523/JNEUROSCI.2936-12.2013

Purpura, D. J., & Ganley, C. M. (2014). Working memory and language: Skills that predict mathematical skills in preschool. Journal of Experimental Child Psychology, 126, 53–69.

Rittle-Johnson, B., & Alibali, M. W. (1999). Conceptual and procedural knowledge of mathematics: Does one lead to the other? Journal of Educational Psychology, 91(1), 175–189.

https://doi.org/10.1037/0022-0663.91.1.175

Robinson, K. M., Dubé, A. K., & Dowker, A. (2012). Children's Use of Arithmetic Shortcuts: The Role of Attitudes in Strategy Choice. Child Development Research, 1(2), 1–10. https://doi.org/10.1155/2012/459385

Robinson, K. M., & LeFevre, J.-A. (2011). The inverse relation between multiplication and division: Concepts, procedures, and a cognitive framework. Educational Studies in Mathematics, 79(3), 409–428. https://doi.org/10.1007/s10649-011-9330-5

Robinson, K. M., & LeFevre, J.-A. (2011). The inverse relation between multiplication and division: Concepts, procedures, and a cognitive framework. Educational Studies in Mathematics, 79(3), 409–428. https://doi.org/10.1007/s10649-011-9330-5

Sasanguie, D., Lyons, I. M., De Smedt, B., & Reynvoet, B. (2017). Unpacking symbolic number comparison and its relation with arithmetic in adults. Cognition, 165, 26–38. https://doi.org/10.1016/j.cognition.2017.04.007

Sasanguie, D., & Vos, H. (2018). About why there is a shift from cardinal to ordinal processing in the association with arithmetic between first and second grade. Developmental Science, 21(5), e12653. https://doi.org/10.1111/desc.12653

Schneider, M., Beeres, K., Coban, L., Merz, S., Susan Schmidt, S., Stricker, J., & De Smedt, B. (2017). Associations of non-symbolic and symbolic numerical magnitude processing with mathematical competence: a meta-analysis. Developmental Science, 20(3), e12372. https://doi.org/10.1111/desc.12372

Siegler, R. S. (2003). Implications of Cognitive Science Research for Mathematics Education. In J. Kilpatrick, W. B. Martin, & D. E. Schifter (Eds.), A research companion to principles and standards for school mathematics (pp. 219–233). National Council of Teachers of Mathematics.

Siegler, R. S., & Braithwaite, D. W. (2017). Numerical Development. Annual Review of Psychology, 68(1), 187–213.

References

https://doi.org/10.1146/annurev-psych-010416-044101

Siegler, R. S., & Ramani, G. B. (2009). Playing linear number board games-but not circular ones improves low-income preschoolers' numerical understanding. Journal of Educational Psychology, 101(3), 545–560. https://doi.org/10.1037/a0014239

Siegler, R. S., Thompson, C. A., & Schneider, M. (2013). An integrated theory of whole number and fractions development. Cognitive Psychology, 62(4), 273–296.

Simmons, F. R., Willis, C., & Adams, A.-M. (2012). Different components of working memory have different relationships with different mathematical skills. https://doi.org/10.1016/j.jecp.2011.08.011

Simsek, E., Jones, I., Hunter, J., & Xenidou-Dervou, I. (2021). Mathematical equivalence assessment: Measurement invariance across six countries. Studies in Educational Evaluation, 70(November 2020), 101046. https://doi.org/10.1016/j.stueduc.2021.101046

Skwarchuk, S. L., & Anglin, J. M. (2002). Children's acquisition of the english cardinal number words: A special case of vocabulary development. Journal of Educational Psychology, 94(1), 107–125. https://doi.org/10.1037/0022-0663.94.1.107

Sowinski, C., LeFevre, J.-A., Skwarchuk, S.-L., Kamawar, D., Bisanz, J., & Smith-Chant, B. L. (2015). Refining the quantitative pathway of the Pathways to Mathematics model. Journal of Experimental Child Psychology, 131, 73–93. https://doi.org/10.1016/j.jecp.2014.11.004

Star, J. R., & Rittle-Johnson, B. (2008). Flexibility in problem solving: The case of equation solving. Learning and Instruction, 18(6), 565–579. https://doi.org/10.1016/j.learninstruc.2007.09.018

VanDerHeyden, A. M., & Peltier, C. J. (2023). Best Practices in School Applications of the Science of Math. In P. Harrison, S. Proctor, & J. Grimes (Eds.), Best Practices in School Psycholgy (7th ed., pp. 253–264). National Assoication of School

References

Psychologists.

Vanderheyden, A. M., & Solomon, B. G. (2023). Valid outcomes for screening and progress monitoring: Fluency is superior to accuracy in curriculum-based measurement. School Psychology (Washington, D.C.), 38(3), 160–172. https://doi.org/10.1037/spq0000528

Xu, C., & LeFevre, J.-A. A. (2016). Training young children on sequential relations among numbers and spatial decomposition: Differential transfer to number line and mental transformation tasks. Developmental Psychology, 52(6), 854–866. https://doi.org/10.1037/dev0000124

Xu, C., & LeFevre, J.-A. (2020). Math fluency and numeracy: Relations with cognitive and symbolic number processing skills. Journal of Educational Psychology, 112(4), 765–780.

Xu, C., & LeFevre, J.-A. (2021). Children's knowledge of symbolic number in grades 1 and 2: Integration of associations. Child Development, 92(3), 1099–1117. https://doi.org/10.1111/cdev.13473

DIVISION SCOLAIRE
LOUIS RIEL
SCHOOL DIVISION