

Preventing Early Mathematics Difficulties: Evidenced Based Principles

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Students with Learning Difficulties



- More than 60% of struggling learners evidence difficulties in mathematics (Light & DeFries, 1995).
- Struggling learners at the elementary level have persistent difficulties at the secondary level, because the curriculum is increasingly sophisticated and abstract.

What Does Research Say Are Effective Instructional Practices For Struggling Students?

- Explicit teacher modeling.
- Student verbal rehearsal of strategy steps during problem solving.
- Using physical or visual representations (or models) to solve problems is beneficial.
- Student achievement data as well as suggestions to improve teaching practices.

What Does Research Say Are Effective Instructional Practices For Struggling Students?

- Cross age tutoring can be beneficial only when tutors are well-trained.
- Goal setting is insufficient to promote mathematics competence
- Providing students with elaborative feedback as well as feedback on their effort is effective (and often underutilized).

Fuchs & Fuchs (2001); Gersten, Chard, & Baker (in review)

Mathematical Proficiency

1. *Conceptual understanding* - comprehension of mathematical concepts, operations, and relations
2. *Procedural fluency* - skill in carrying out procedures flexibly, accurately, efficiently, and appropriately
3. *Strategic competence* - ability to formulate, represent, and solve mathematical problems
4. *Adaptive reasoning* - capacity for logical thought, reflection, explanation, and justification
5. *Productive disposition* - habitual inclination to see mathematics as sensible, useful, and worthwhile, coupled with a belief in diligence and one's own efficacy.

Common Difficulty Areas for Struggling Learners

**Memory and Conceptual
Difficulties**

**Background Knowledge
Deficits**

**Linguistic and Vocabulary
Difficulties**

**Strategy Knowledge
and Use**

Memory and Conceptual Difficulties

Students experience problems:

- Remembering key principles;
- Understanding critical features of a concept;
- Because they attend to irrelevant features of a concept or problem.

Addressing Diverse Learners Through Core Instruction

Memory and Conceptual Difficulties

Thoroughly develop concepts, principles, and strategies using multiple representations.

Gradually develop knowledge and skills that move from simple to complex.

Include non-examples to teach students to focus on relevant features.

Include a planful system of review.

Primary

Big Idea - Number

Plan and design instruction that:

- Develops student understanding from concrete to conceptual,
- Scaffolds support from teacher \Rightarrow peer \Rightarrow independent application.

Primary

Sequencing Skills and Strategies

Adding w/ manipulatives/fingers

Adding w/ semi-concrete objects

Adding using a number line

Min strategy

Missing addend addition

Addition number family facts

Mental addition (+1, +2, +0)

Addition fact memorization

Concrete/
conceptual



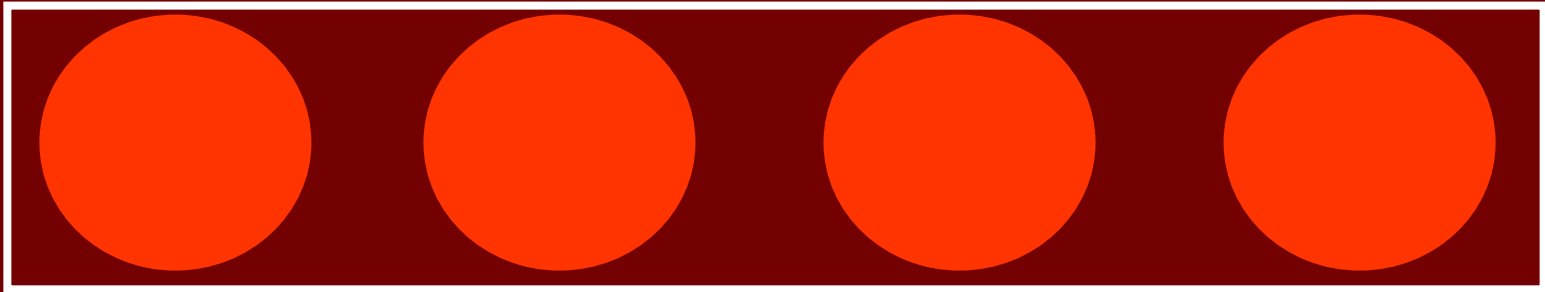
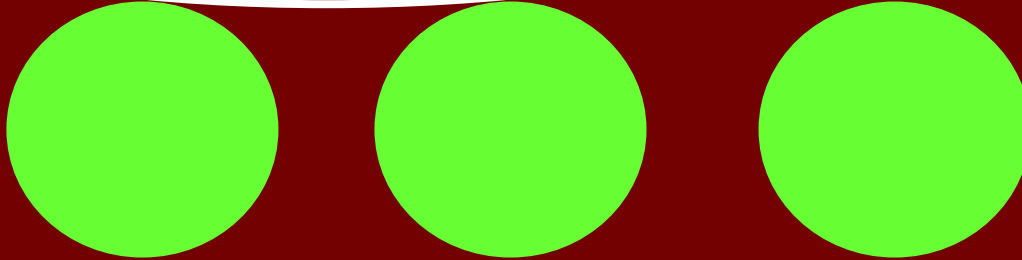
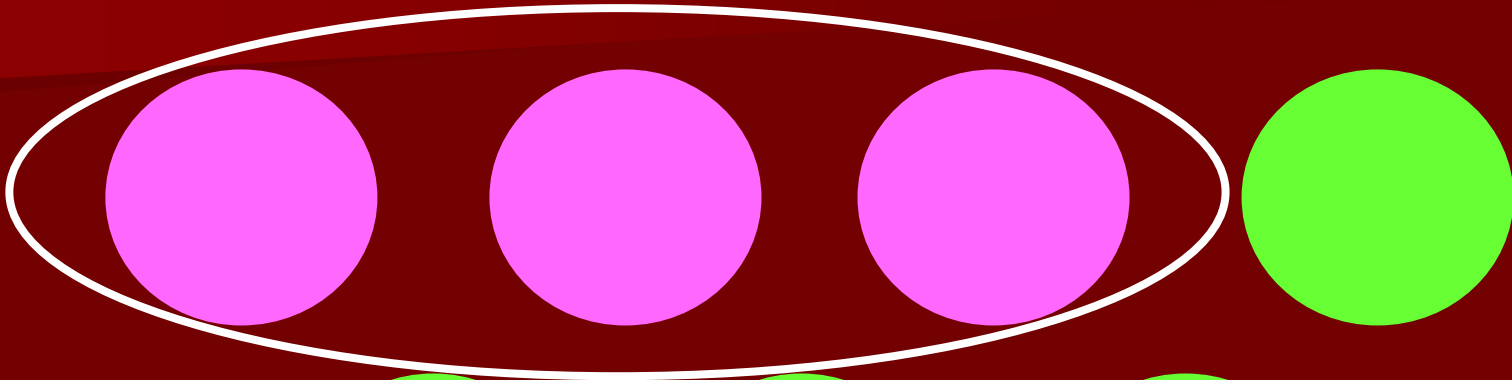
Semi-concrete/
representational



Abstract

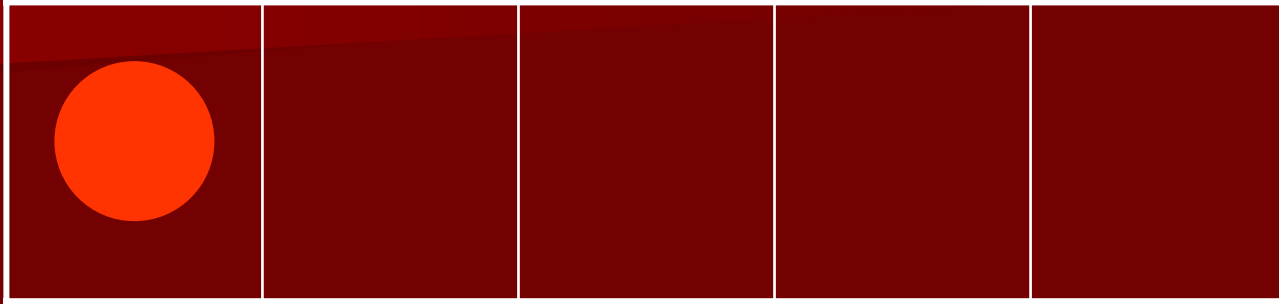
Intermediate

Rational Numbers



Intermediate

Rational Numbers

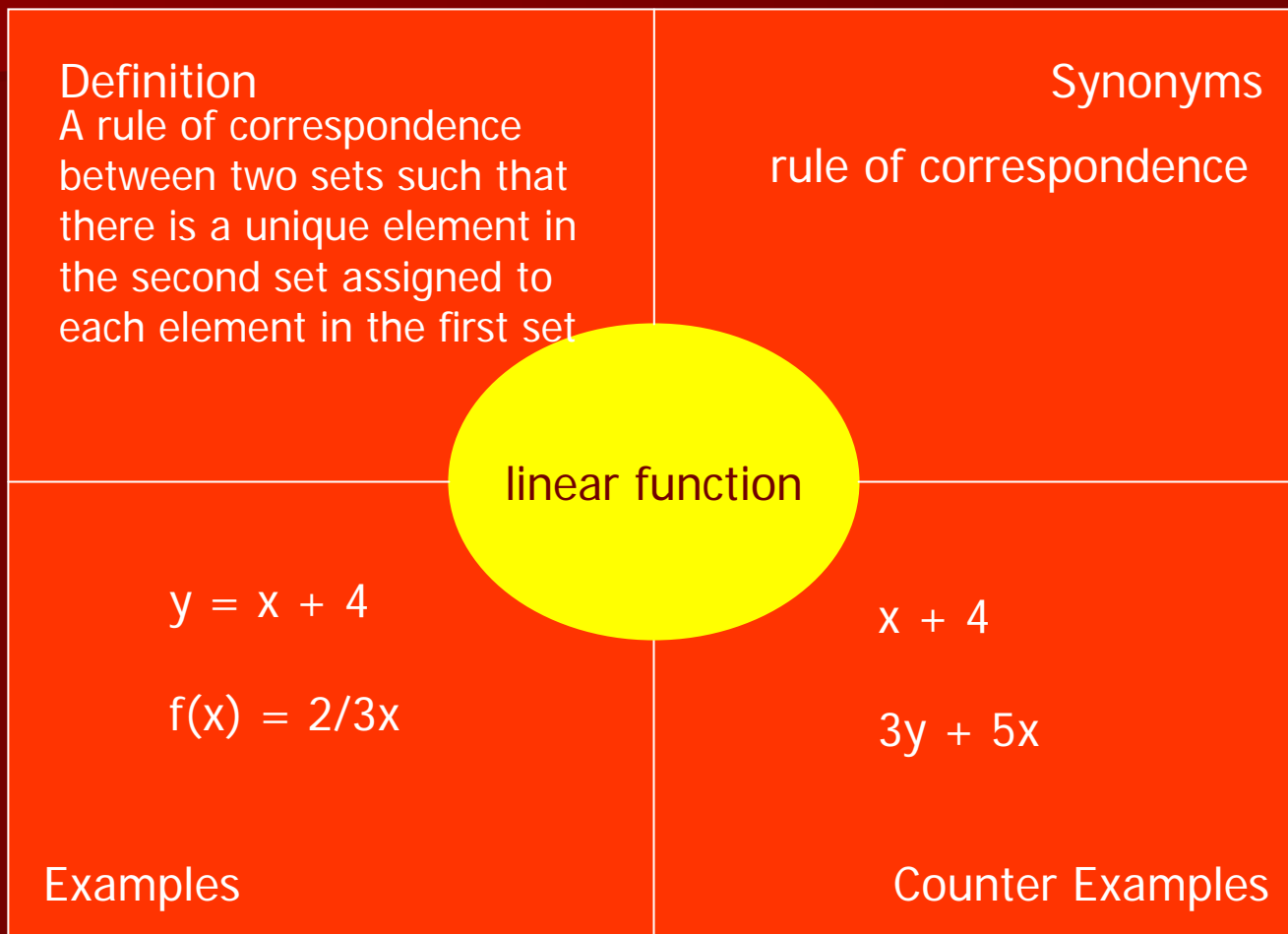


What rational number represents the filled spaces?

What rational number represents the empty spaces?

What is the relationship between the filled and empty spaces?

Presenting Rational Numbers Conceptually

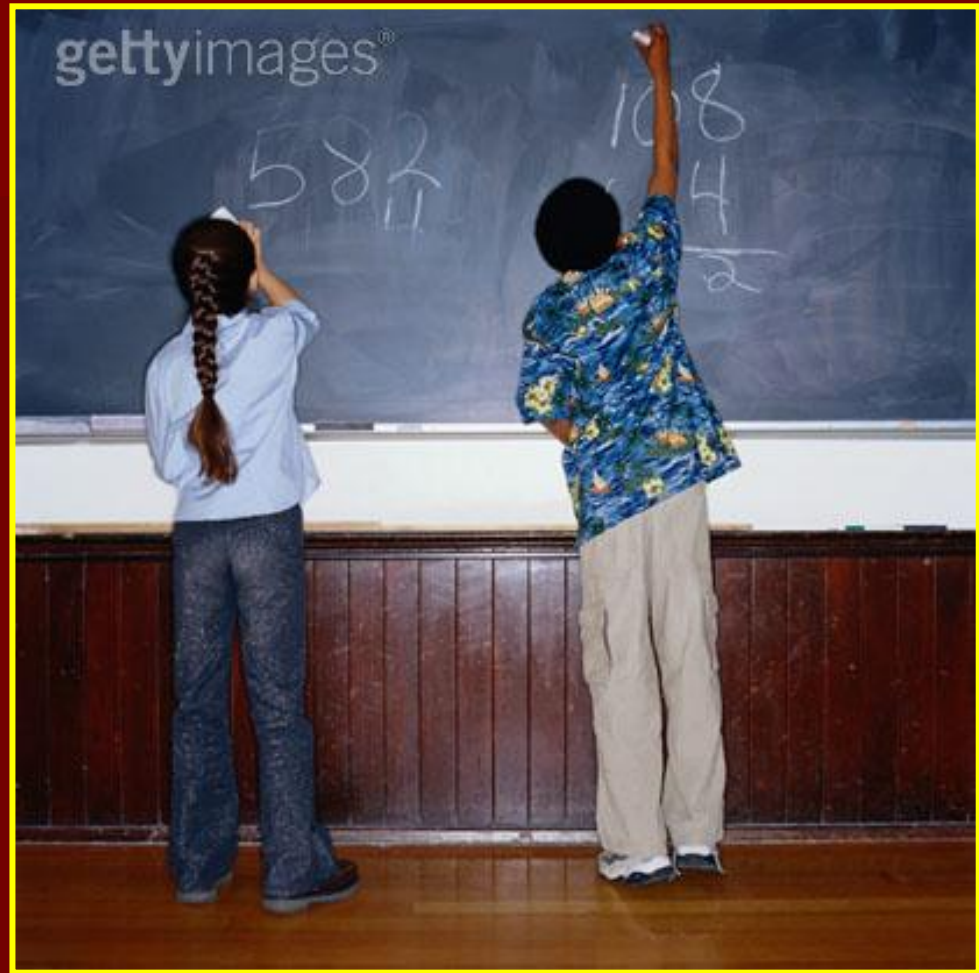


Background Knowledge Deficits

Students experience problems:

- With a lack of early number sense;
- Due to inadequate instruction in key concepts, skills, and strategies;
- Due to a lack of fluency with key skills.

For many students struggling with mathematics, mastery of key procedures is dependent on having adequate practice to build fluency.



Addressing Diverse Learners Through Core Instruction

**Background Knowledge
Deficits**

**Identify and preteach
prerequisite knowledge.**

Assess background knowledge.

**Differentiate practice and
scaffolding.**

Number Families



$$4 + 3 = 7$$

$$7 - 4 = 3$$

$$3 + 4 = 7$$

$$7 - 3 = 4$$

Fact Memorization



$$\begin{array}{r} 5 \\ +2 \\ \hline \end{array}$$

$$\begin{array}{r} 3 \\ +6 \\ \hline \end{array}$$

$1 + 8 =$

$4 + 3 =$

$$\begin{array}{r} 4 \\ +4 \\ \hline \end{array}$$

$$\begin{array}{r} 2 \\ +7 \\ \hline \end{array}$$



$5 + 2 =$

$6 + 0 =$

$$13 - 5 = \square$$

$+10$ $+3$ -3 -2

“Manipulative Mode”

Linguistic and Vocabulary Difficulties

Students experience problems:

- Distinguishing important symbols;
- With foundation and domain specific vocabulary;
- With independent word recognition.

Strategy Knowledge and Use

Students experience problems:

- Remembering steps in a strategy;
- Developing self-questioning skills;
- Selecting an appropriate strategy to fit a particular problem.

Project Staff

- David Chard, Principal Investigator, University of Oregon
- Scott Baker, Principal Investigator, Pacific Institutes for Research
- Kathleen Jungjohann, University of Oregon
- Ben Clarke, Pacific Institutes for Research
- Karen Davis, Pacific Institutes for Research
- Eunju Jung, University of Oregon

Project Objectives

- Develop and evaluate the efficacy of a mathematics instructional intervention for kindergarten
- Develop a progress monitoring system designed to address the instructional needs of kindergarten students in:
 - Whole number and number operations
 - Measurement
 - Geometry
 - Mathematical vocabulary

Conceptual Framework



Development of
Mathematical
Models

Mathematics-related
Vocabulary and
Discourse

Procedural Fluency
and Automaticity

Mathematics-related Vocabulary & Discourse

- Focus on decontextualized word knowledge (Biemiller, 2001; Snow et al., 1998)
- Modeling of discussions to substantiate and clarify student understanding (Pressley & McCormick, 1995; Roehler & Cantlon, 1997)
- Development of domain specific vocabulary (Stahl & Fairbanks, 1986)

Procedural Fluency and Automaticity

- Deliberate design to build fluency with key skills to support conceptual understanding
- Focus on technology to support fluency building

Independent Variable

- Instructional program based on the following features:
 - Weekly units targeting key areas
 - Daily, 20-minute whole class lessons incorporating multiple math strands
 - Content explicitly taught and reviewed
 - Regular opportunities to engage in automaticity software
 - Weekly problem solving events to challenge students to think and discuss approaches to problems
 - Vocabulary instruction integrated across strands

Guiding Research Questions

- Year 1: Design Experiment
 - What instructional strategies, materials, and activities, most effectively help students (a) develop representations of math concepts, (b) build vocabulary and discourse, and (c) enhance procedural fluency?
 - What student performance measures can be used to assess student development of focus areas?
 - What observation protocols can be used to reliably assess (a) instructional fidelity and (b) engagement and participation in key instructional objectives?

Year 2: Formal Experiment I

- What is the impact of the intervention on student achievement on standardized assessments? on measures designed to directly assess learning of specific intervention content?
- Is there differential impact based on student status at entry into kindergarten?
- What student engagement and participation features during instruction predict learning outcomes?

Year 3: Formal Experiment II

- What impact does highly specified intervention procedures have on the mathematics learning and achievement of students most at risk of mathematics difficulties?
- What impact does instruction designed to facilitate more intense small group instruction have on overall student engagement and participation rates?

Research Design: Year 1

- Design Experiments
 - Objectives:
 - Pilot instructional lessons
 - Pilot performance assessments
 - Develop and pilot observation instruments

Research Design: Year 2

- Quasi-Experimental Design
- Participants: 14 Classrooms randomly assigned to experimental and comparison conditions; 8 target students (4 at-risk; 4 average)
- Focus on schools with high poverty and high English learner populations

Research Design: Year 2 (cont.)

■ Dependent Measures

- Student Measures

- Stanford Achievement Test - 10 (Pre-Post)
- Number Knowledge Test (Okamoto & Case, 1996) (Pre-Post)
- Early Numeracy-CBM (Chard et al., 2005; Clarke & Shinn, 2003) (Pre-Post)
- Performance Measures (3X during the study, aligned with problem solving activities)

Research Design: Year 2 (cont.)

■ Measures

- Classroom Observations

- Intervention Fidelity (monthly)
- Student Participation and Engagement (4X per target student during the study)

- Teacher Measures

- Levels of Use Interviews (Hall & Hord, 2001; Loucks, Newlove, & Hall, 1975)
- Stages of Concern Questionnaire (Hall & Loucks, 1978)

Research Design: Year 3

- Quasi-Experimental Design
- Participants: Same teachers as in Year 2; 8 target students per class; Year 2 students in grade 2 will be assessed at the end of the year to determine long-term impact
- Measures
 - Same as in Year 2

Proposed Data Analysis

- Focus on between group differences using analysis procedures to assess intervention impact (Stoolmiller et al., 2000)
- Secondary analysis after Year 3 to determine effects of 2nd year of implementation
- Case studies on 10 teachers that will focus on teacher change as a result of implementation

Student Materials



Lesson 4

3 Three silly squirrels,
With three fluffy tails.
Hiding nuts and berries,
Along three windy trails.



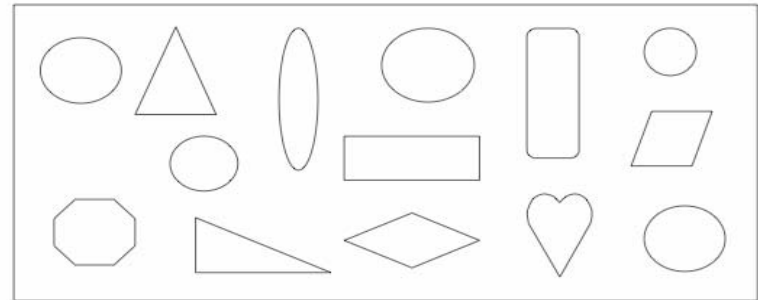
3 Three nuts here,
Three berries there,
Can you find and count them
Before the hungry bear?



Name and trace numeral 3 and 2.

3	3	3	3	3	3
2	2	2	2	2	2

Find all the circles. Make them all the same color.



Note home

- Read the chant while your child follows along or reads along with you. Have them hold up 3 fingers each time they hear three. Have them count things that are 3.
- Have your child tell you what numbers they traced.
- Ask your child what shape they colored and how the circles are the same.
- * The activities above will help your child master these concepts and skills. We will continue to work on these skills at school.

Progress Monitoring Measures

Quantity Discrimination

3 7	5 2	6 8
1 8	3 6	9 5
4 2	1 7	6 2
8 3	7 5	3 4

Missing Number

3 4 _	5 6 _	6 7 _
1 2 _	2 3 _	7 8 _
4 5 6	2 3 _	6 7 _
7 8 _	5 6 _	3 4 _

Automaticity Builder Software (Intellitools, 2004)

$$\begin{array}{r} 13 \\ - 5 \\ \hline \end{array} = \square$$

$+10$ $+3$ -3 -2

“Manipulative Mode”

Research on Assessment Component

- Research Line 1: Early Numeracy Curriculum-Based Measurement Four experimental measures (Clarke & Shinn, 2003)
 - EN-CBM Oral Counting measure
 - Students orally count for one minute. No student materials.
 - EN-CBM Number Identification measure

13	1	12	4	8	17	11	6
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Assessment Component (cont.)

- EN-CBM Quantity Discrimination measure

12	3	4	1	5	11	9	4
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- EN-CBM Missing Number measure

12 13 ___	6 7 ___	3 4 ___
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- Criterion measures
 - CBM first grade math probes
 - WJ Applied-Problems subtest
 - Number Knowledge Test

Summary of Findings

- All had adequate reliability and validity for educational decision making
- QD from a traditional standpoint had the strongest evidence, OC had the weakest
- For use in early identification and formative evaluation, different measures had strengths and weaknesses.

Current Research

- Conduct research with Kindergarten sample
- Longitudinal research on math trajectories and predictive validity of experimental measures
- Investigate sensitivity to growth

Next Steps

- Reliability data
- Long term predictive validity
- Continued examination of criterion/cut scores
- Analysis of ability to model growth over time and response to intervention