


# Busting Myths To Align Instruction & Intervention With The Science of Math

Kansas MTSS ~ January 25, 2023  
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**Session Goals:**

- Present common myths you may encounter in practice.
- Discuss the best available evidence relative to these myths.
- Provide talking points to challenge the myths and recommend alternatives.

**MYTH**  
 /mith/  
 a widely held but false belief

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# Overview

1. Teach Conceptual Knowledge 1<sup>st</sup>
2. Standard Algorithms are Harmful
3. Productive Struggle Leads to Deeper Learning
4. Explicit Instruction is Only Helpful for Some Students
5. All Standards Are Created Equal
6. Executive Functioning Training Matters
7. Growth Mindset Increases Math Achievement

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Estimate the closest whole number of  $\frac{12}{13} + \frac{7}{8}$

- Understand and estimate magnitude

Decide whether  $3 = 3$  makes sense

- Evaluate examples of concepts

Place 28 on a number line

- Translate quantities between representational systems

Which is bigger: 5 or 8

- Compare quantities

Define the equal sign

- Generate or select definitions

## Defining Terms: Conceptual

**Comprehension of  
mathematical  
concepts, laws,  
principles, & relations**  
(Kilpatrick et al. 2001, p. 5)

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$$8/10 + 6/10 = x$$

- Solve problems in a familiar format

$$2 \frac{1}{2} + \frac{1}{4} = x$$

- Solve problem with a new surface or problem feature

$$5 + 4 =$$

- Quick and effortless recall of basic facts

$$58 + 62 =$$

- Solve complex operations using algorithms, mental math, and other strategies as appropriate

## Defining Terms: Procedural

**Knowledge of when &  
how to use procedures  
appropriately as well as  
skill in performing  
them flexibly,  
accurately & efficiently**  
(Kilpatrick et al., p. 121)

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**Intertwined Strands of Proficiency**

# Truth

Pitting procedural fluency against conceptual understanding **creates a FALSE DICHOTOMY** (NCR, 2001, p. 100)

Conceptual understanding and procedural fluency (including quick & effortless recall of facts) are **MUTUALLY BENEFICIAL** (NMAP, 2008, p. 11)

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**Procedural vs. Conceptual Debate** seems only to apply to U.S.

Other countries recognize practice with procedures as a route to understanding

## U.S. Curricula

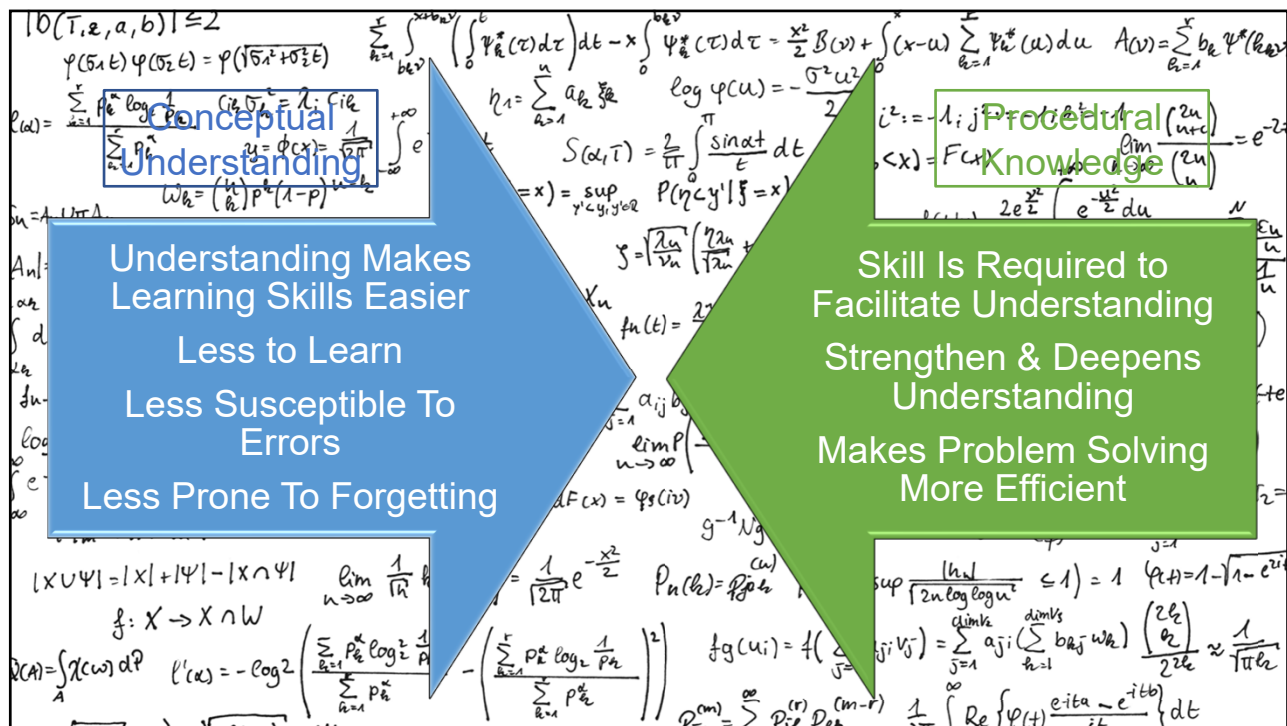
### Gaps in BOTH Conceptual & Procedural Knowledge

U.S. students cannot solve basic facts as quickly or efficiently as their international peers

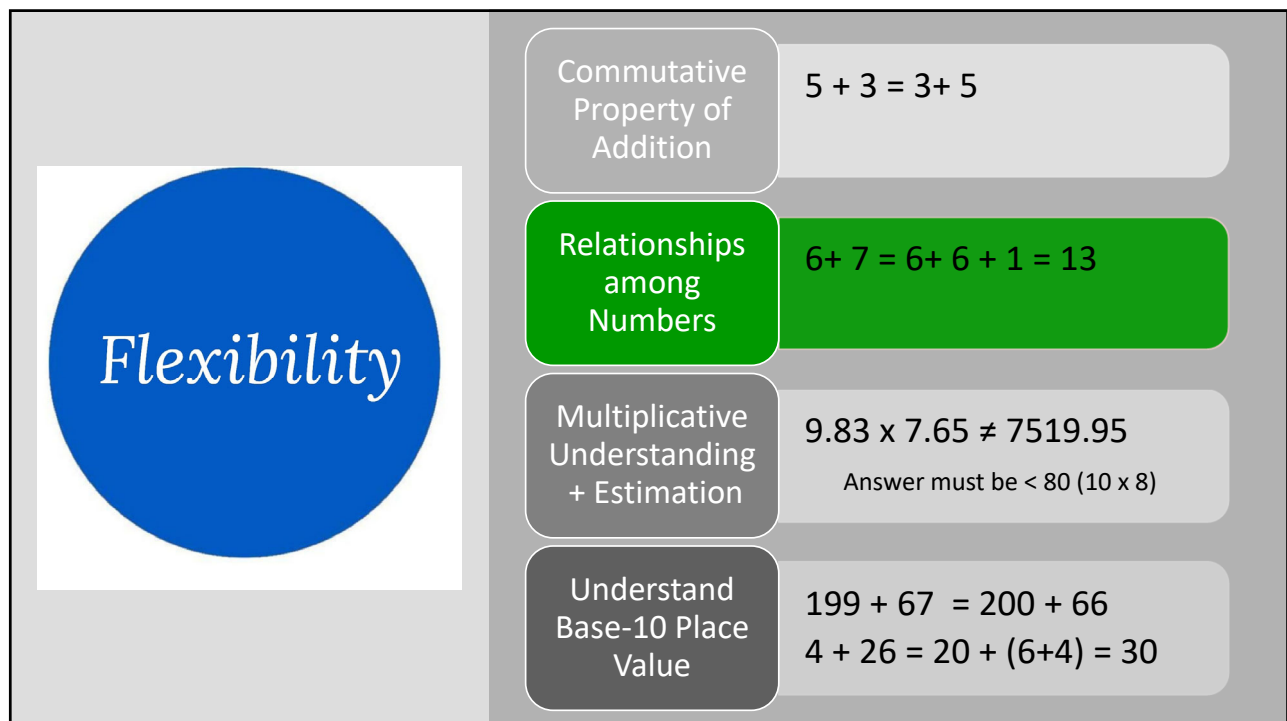
Neither textbooks nor instruction provide enough opportunities for practice with procedural knowledge

(Coddington et al., 2017; NCR, 2001; NMAP, 2008)

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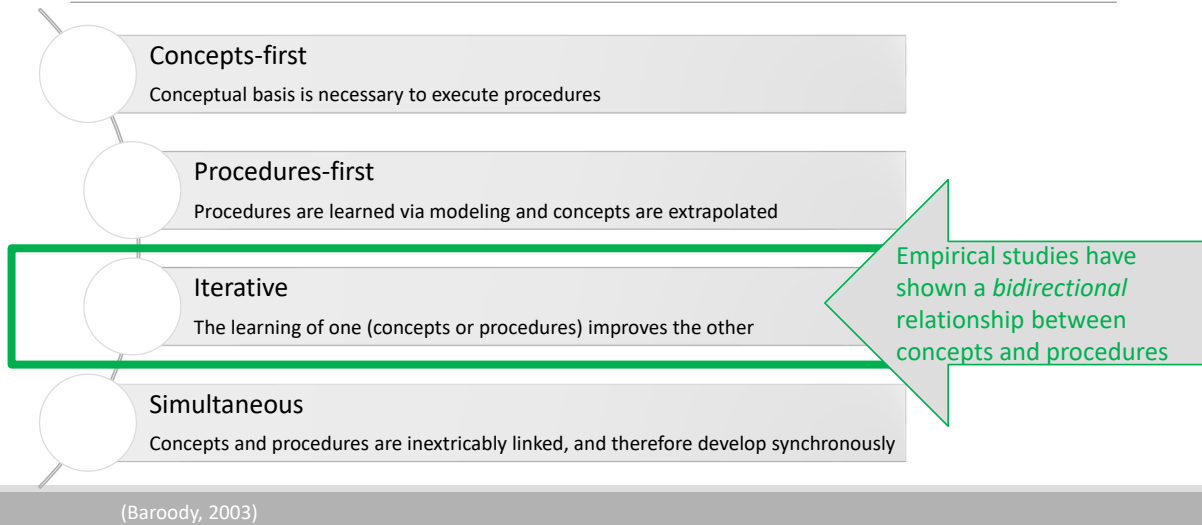
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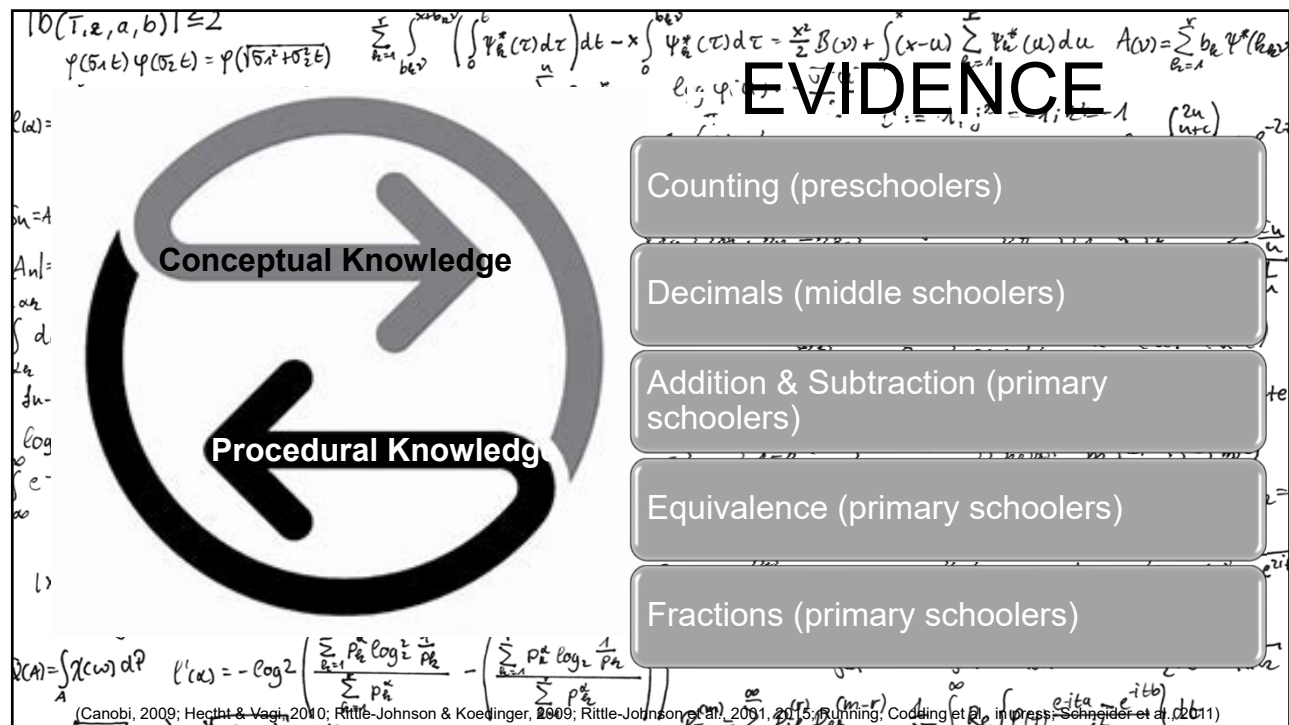
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# Theories Regarding the Relationship Between Conceptual Understanding & Procedural Fluency



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## Best Practices

Interleave conceptual  
and procedural content  
within lessons

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## ***MYTH #1 HAS LED TO THESE OTHER MYTHS:***

*Standard Algorithms are Harmful  
Fact Fluency Doesn't Matter*

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has 38 boxes of oranges in her delivery truck. Each box holds 12 oranges. How many oranges does Julie have in her truck?

456

$$\begin{array}{r} 1 \\ 38 \\ \times 12 \\ \hline 176 \\ + 380 \\ \hline 456 \end{array}$$

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Linking Strands of Mathematical Proficiency to Number Combinations

Algorithm-only instruction is distinct from not teaching the standard algorithm at all

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102

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# Logic of Standard Algorithm

1. Add digits in the ones column:  $4 + 8 = 12$

2. If the sum in the ones column is  $> 10$ , regroup:  $12 = 10 + 2$

3. Sum the digits in the tens column:  $5 + 4 + 1 = 10$

4. Sum the digits in the hundreds column:  $1 + 0 = 1$

Final result:  $102$

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# Truth

Many Tasks In Every Day Life Require Algorithms

Algorithms...

- link conceptual understanding & procedural knowledge
- permit understanding that mathematics is structured, predictable, organized & contains patterns

Tool For Completing Routine Tasks

Mechanism For Breaking Down More Complex Problems Into Simpler Subtasks

(Kilpatrick et al., 2001; Wu, 2011)

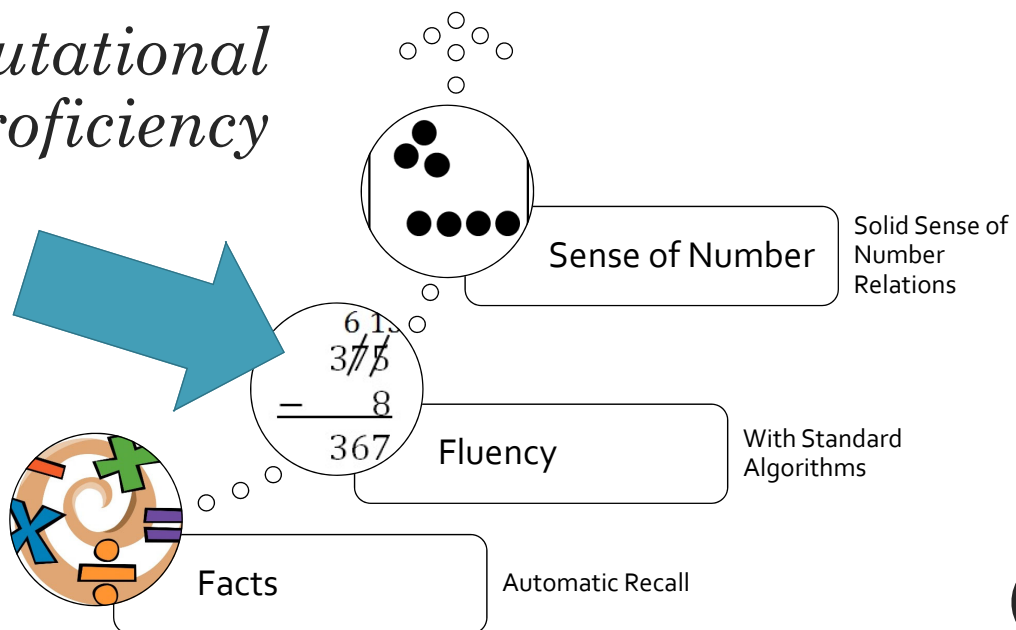
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The National  
Mathematics  
Advisory  
Panel (2008)  
defines  
**Proficiency**  
as...

Understanding key concepts,  
achieve automaticity as  
appropriate, **DEVELOP  
FLEXIBLE ACCURATE, &  
AUTOMATIC EXECUTION OF  
STANDARD ALGORITHMS**, &  
use these competencies to solve  
problems (p. 22)

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## *Computational Proficiency*



(National Mathematics Advisory Panel, 2008)

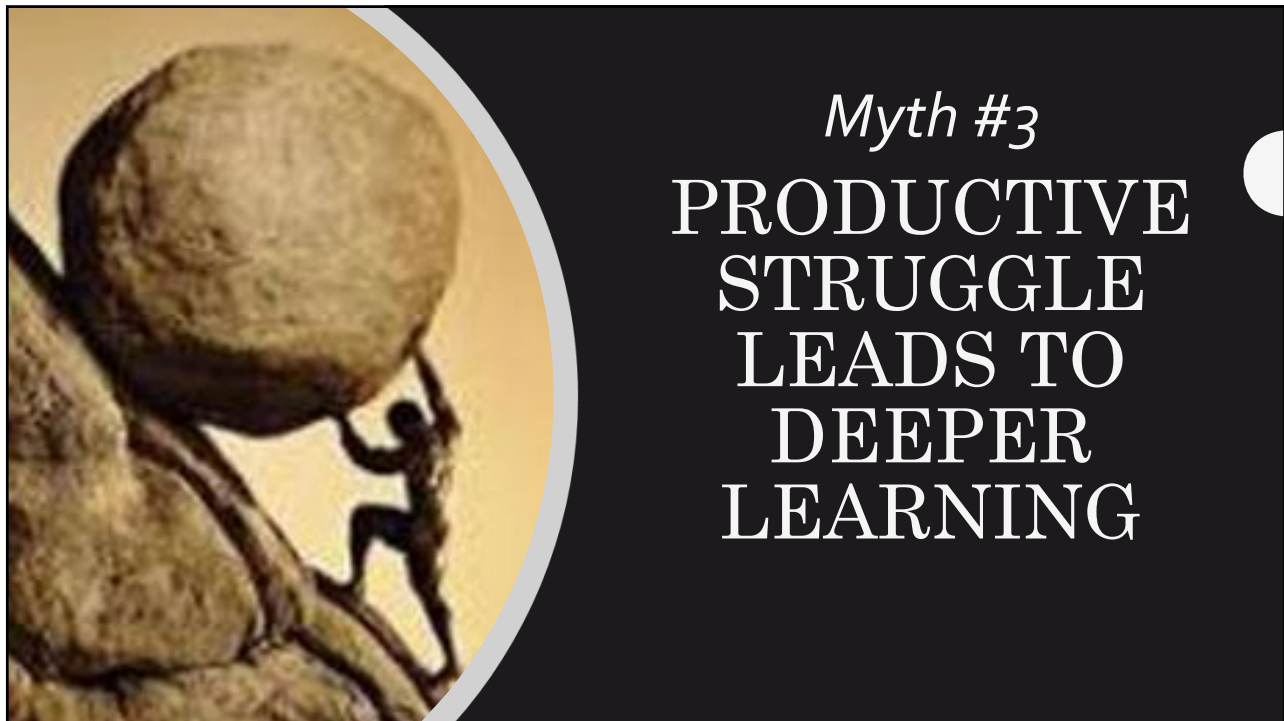
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# BEST PRACTICES

Help  
Students  
Understand  
When to  
Use & Why

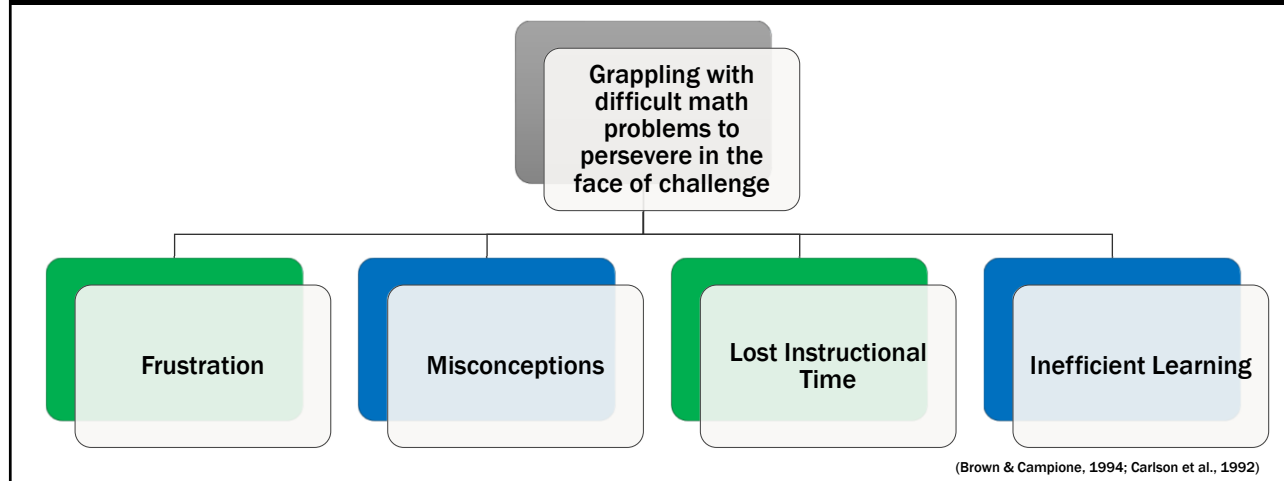
Teach the  
Standard  
Algorithm

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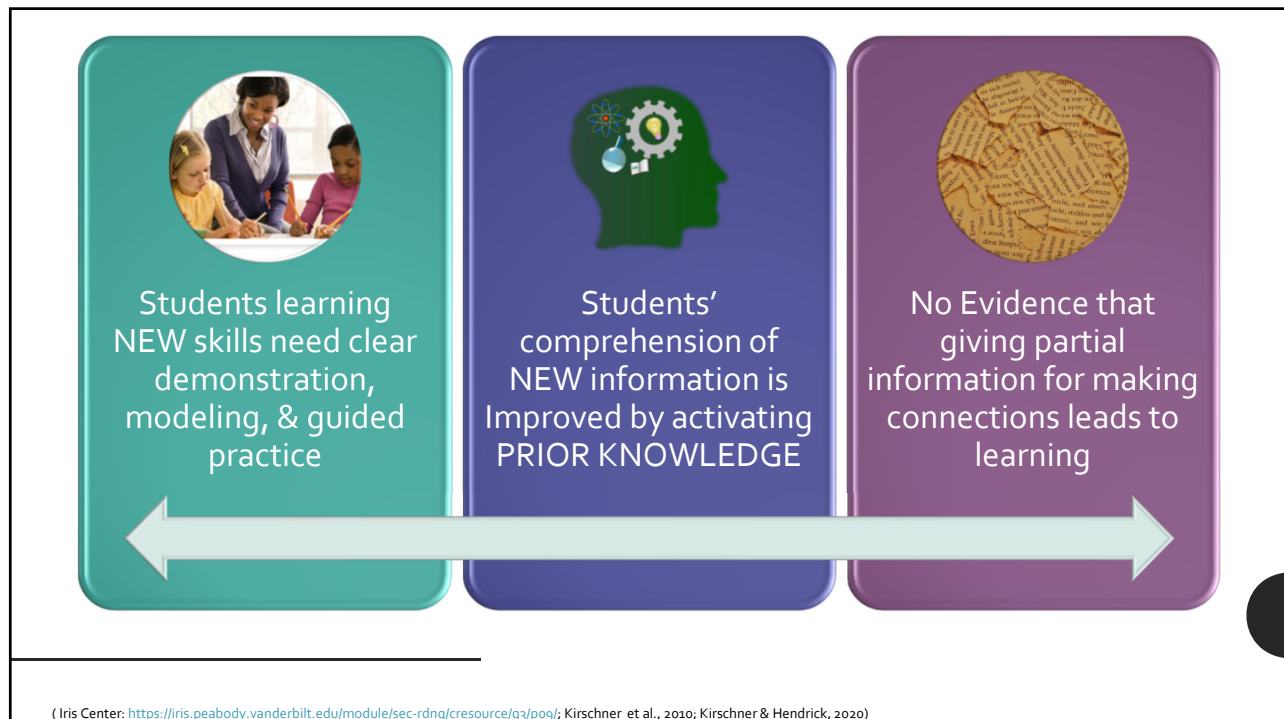


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# PRODUCTIVE STRUGGLE



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(Iris Center: <https://iris.peabody.vanderbilt.edu/module/sec-rdng/cresource/q3/pogj/>; Kirschner et al., 2010; Kirschner & Hendrick, 2020)

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# Instructional Hierarchy



(Burns et al., 2010; Coddling et al., 2017; Haring et al., 1978)

## Acquisition

**ESTABLISHING** Skills & Concepts – Building Accuracy



## Fluency

**REMEMBERING & RETAINING** Skills & Concepts – Building Efficiency & Accuracy



## Generalization

**ENDURING** – Skills & Concepts Are Demonstrated Across Academic Tasks & Situations



## Adaptation

**APPLYING** – Skills & Concepts are Integrated and Applied to Novel Problems

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# Best Practices



### Scaffold

Scaffold Learning According to the Instructional Hierarchy

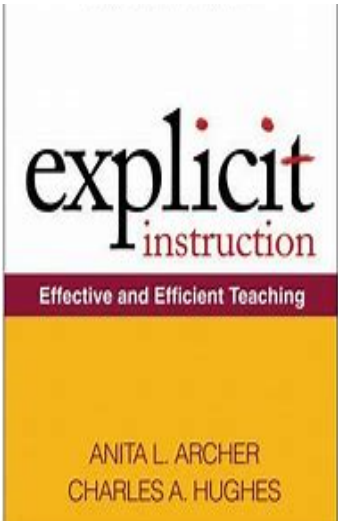
### Build on

Build on Prior Knowledge

### Provide

Provide Challenging Problems After Students Demonstrate Accuracy, Fluency, & Generalization w/Required Skills & Concepts

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*Myth #4*

# EXPLICIT INSTRUCTION IS ONLY HELPFUL FOR SOME STUDENTS

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*Explicit Instruction*

Systematic

STATED CLEARLY AND IN DETAIL, LEAVING NO ROOM FOR CONFUSION OR DOUBT.

~Oxford Dictionary of Learning and Skills (Doabler et al., 2014; Carnine et al., 2004)

- Teacher-Directed

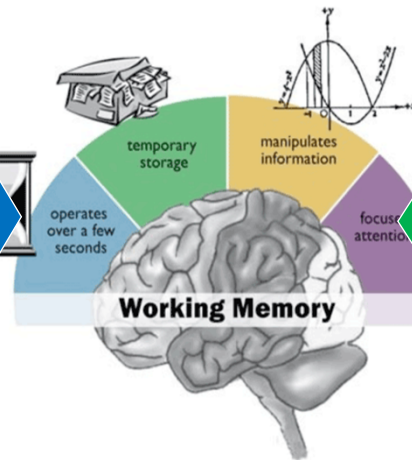
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# SCIENCE OF LEARNING

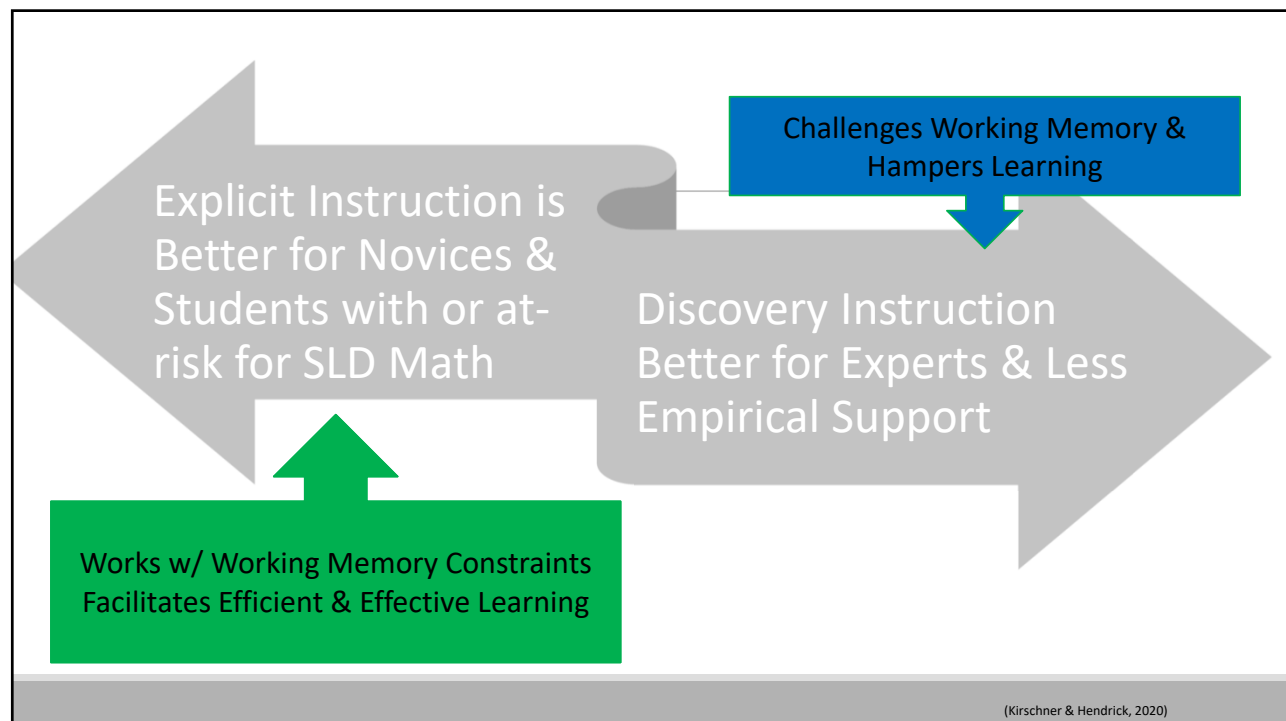
## Novice Learners:

- Limited prior knowledge
- Remember & process parts
- Use inefficient problem-solving tactics
- Work backwards



(Doabler et al., 2015; Smith et al., 2016)

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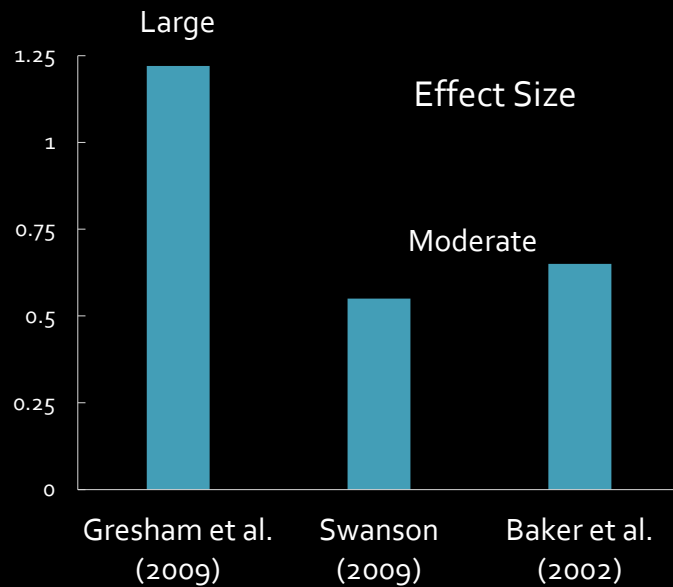
(Kirschner & Hendrick, 2020)

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# Evidence

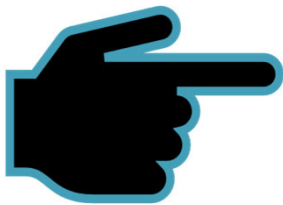
Students with math difficulties & disabilities **BENEFIT MORE** from explicit instruction than discovery-oriented methods

(Kroesbergen & Van Luit, 2003)



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# Truth



Clear and concise demonstrations

Frequent OTPs to verbalize

Timely feedback

High quality & frequent teacher-student interactions

Scaffolding according to instructional level

Evaluates for mastery

(Doabler et al., 2015)

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IES WWC What Works Clearinghouse

PRACTICE GUIDE

Assisting Students Struggling with Mathematics: Intervention in the Elementary Grades

Released: March 2021 PDF (1.9 MB)

Recommendations Details Panel

This practice guide presents evidence-based practices that can help teachers tailor their instructional approaches and/or their mathematics intervention programs to meet the needs of their students.

- 1 Systematic Instruction:** Provide systematic instruction during intervention to develop student understanding of mathematical ideas. **STRONG EVIDENCE**
- 2 Mathematical Language:** Teach clear and concise mathematical language and support students' use of the language to help students effectively communicate their understanding of mathematical concepts. **STRONG EVIDENCE**
- 3 Representations:** Use a well-chosen set of concrete and semi-concrete representations to support students' learning of mathematical concepts and procedures. **STRONG EVIDENCE**
- 4 Number Lines:** Use the number line to facilitate the learning of mathematical concepts and procedures, build understanding of grade-level material, and prepare for advanced mathematics. **STRONG EVIDENCE**

▼ Show More

▼ Show More

▼ Show More

# Best Practices

- Incorporate Explicit Instruction into Core Instruction
- Use a Curriculum that Incorporates Explicit Instruction
- Provide Explicit Instruction During Tiered Intervention supports

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Myth #5

ALL MATH STANDARDS ARE CREATED EQUAL

COMMON CORE STATE STANDARDS INITIATIVE

COMPARING AMERICA'S STUDENTS FOR COLLEGE & CAREER READY

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## History: A Mile Wide & an Inch Deep



Number of Math Topics Listed (Schmidt & Houang, 2012)	Grade Level				
	First	Second	Third	Fourth	Fifth
A+ International Countries	5	9	12	16	21
Common Core Mathematics Standards	8	11	13	17	21
Sample of 50 States' Mathematics Standards (2008-2009)	13	15	18	20	21
State Averages (1995)	12	17	21	26	28

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## Critical Foundations for Algebra

Algebra

Whole Number Proficiency

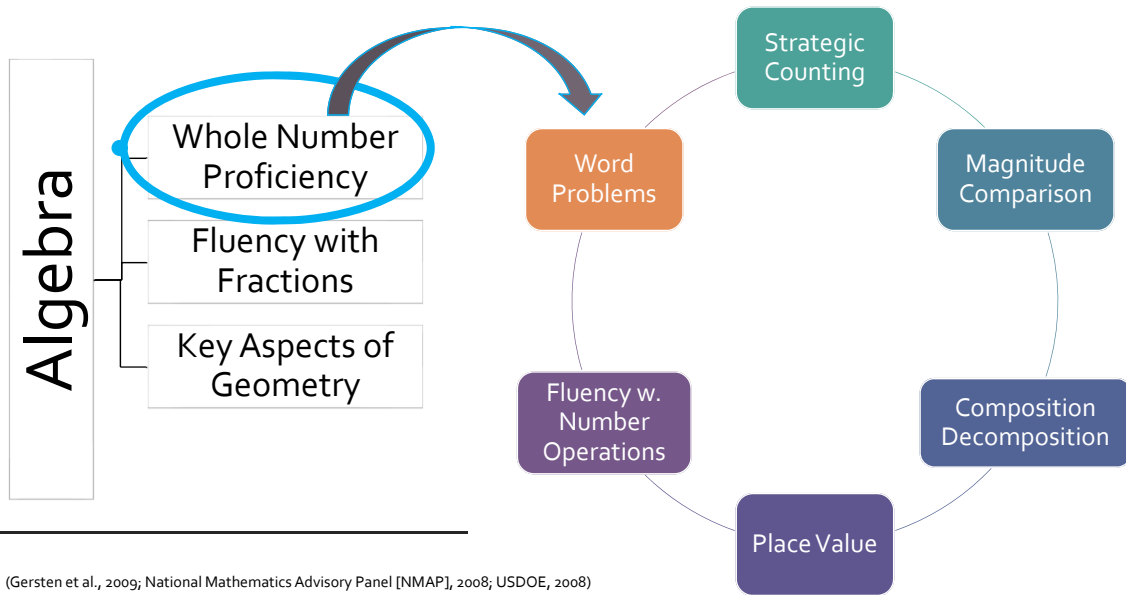
Fluency with Fractions

Key Aspects of Geometry

(Gersten et al., 2009; National Mathematics Advisory Panel [NMAP], 2008; USDOE, 2008)

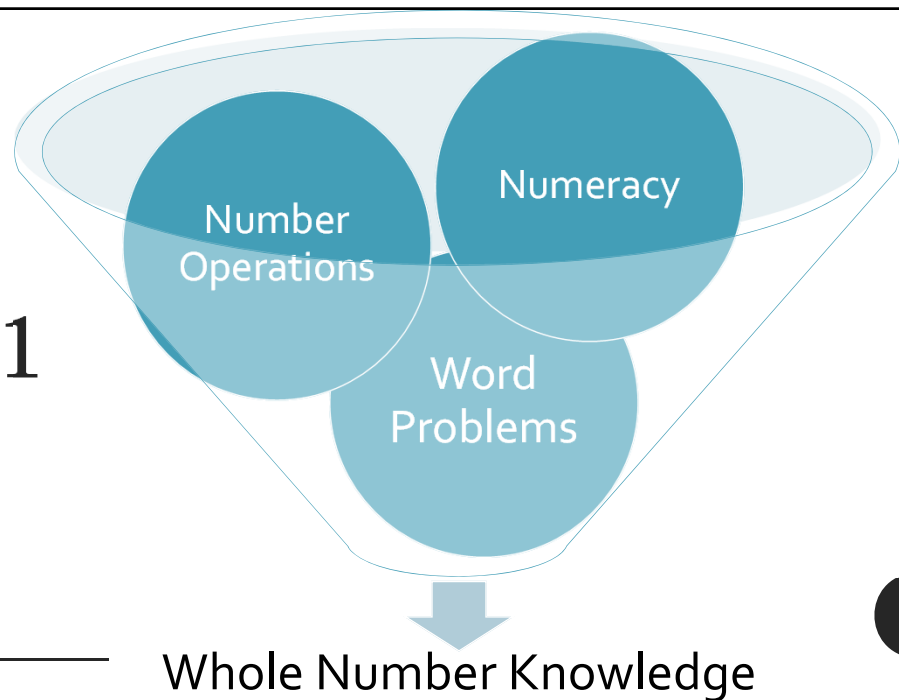
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## Key Content Targets for Mastery (K-5)

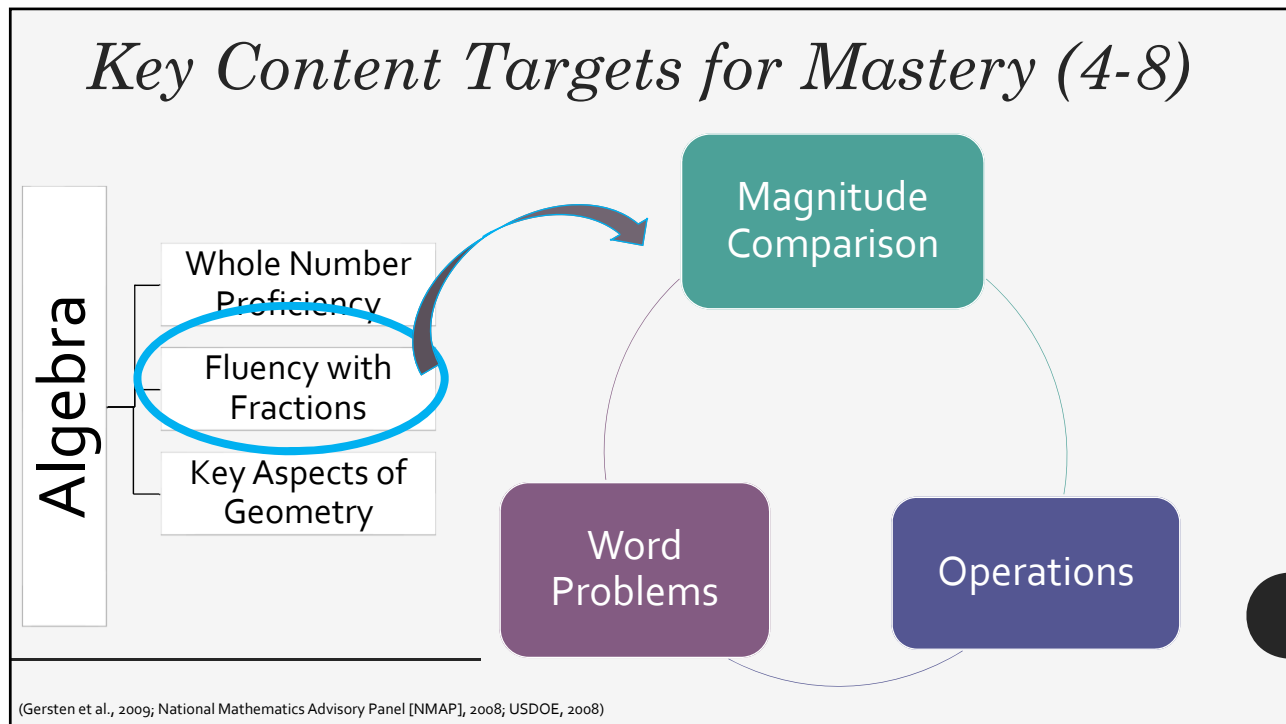


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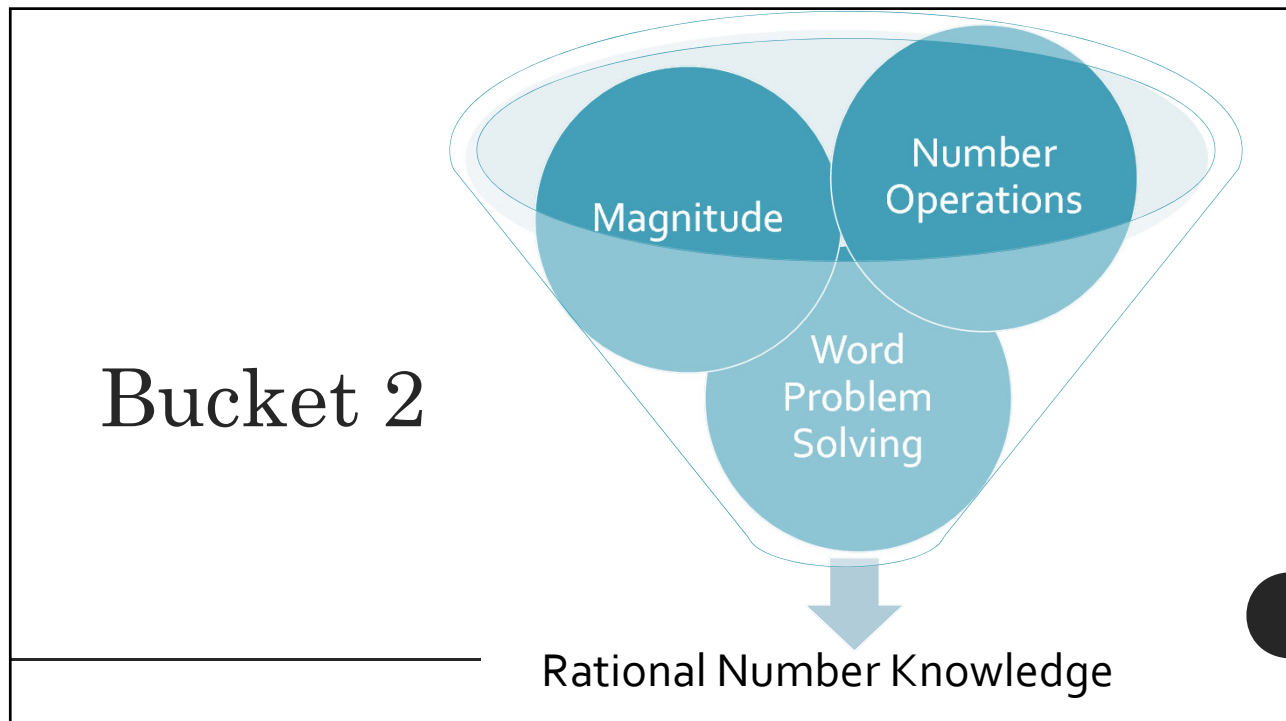
## Bucket 1



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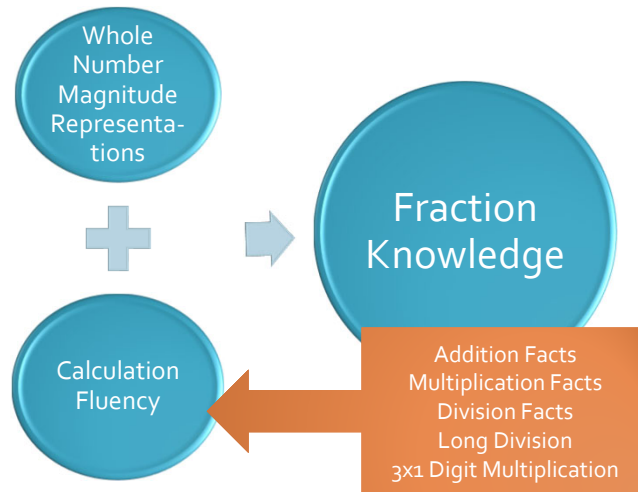


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Students with **somewhat or more severe** whole number difficulty were **MORE LIKELY** to experience **DIFFICULTY** in fraction understanding than students with adequate whole number knowledge

## Relationship Between Whole & Rational Number Knowledge



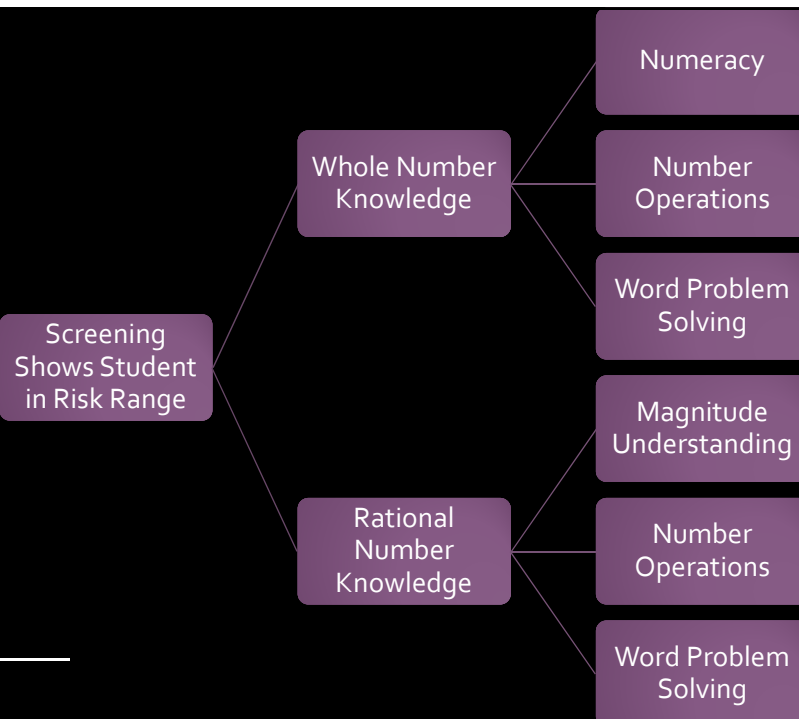
(Hansen, Jordan, & Rodrigues, 2017; Ilyse et al., 2016; Numkung et al., 2018; Resnick et al 2018)

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Best Practices:

K-8 Emphasis

Teach Foundational Skills 1<sup>st</sup>




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*Myth #6*

# EXECUTIVE FUNCTIONING TRAINING MATTERS

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## Executive Functioning: What is it?

Set of cognitive skills required to direct behavior toward a goal by planning, focusing attention, remembering, & juggling tasks

Refers to

- Working Memory
- Mental Flexibility
- Self-control

Responsible for the following skills

- Regulating emotions
- Planning, organizing, prioritizing
- Self-monitoring (keeping track of what you are doing)
- Inhibition
- Persisting on Tasks

[What Is Executive Function? | Understood](#)

[A Guide to Executive Function - Center on the Developing Child at Harvard University](#)

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## Relationship between Achievement & EF



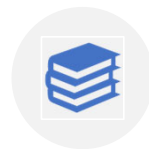
Moderate association  
(average correlation = .31)  
between EF and math  
achievement



This relationship was  
reduced when studies  
controlled for IQ and other  
background characteristics



Very few rigorous EF training  
intervention studies exist



EF training interventions  
improved EF functioning but  
**not academic outcomes**

(Jacob & Parkinson, 2015)

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**Bottom Line: the way the math activities were constructed was altered to address individual cognitive differences**

### What about Individual Differences?

Number knowledge intervention with fluency building or conceptual knowledge activities	
Regardless of cognitive reasoning skills (weak or strong) improvement occurred with fluency building version	For students with weak reasoning ability, the conceptual activity version led to poorer outcomes than students with stronger reasoning ability

Fraction intervention with either fluency or conceptual practice activities	
Students with very poor working memory scores did better with the conceptual practice version	Students with better working memory scores did better with fluency practice version

(Fuchs et al., 2013; Fuchs et al, 2014)

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The most effective way to address math skill deficits is to DIRECTLY remediate math skills

## Best Practices

### To Individualize Math Interventions

- Minimize cognitive load on working memory and reasoning by
  - *including explicit instruction & breaking down problems into smaller more manageable parts*
- Minimize excessive language load by
  - *using visual and concrete representations and providing fluency practice*
- Increase repetition and opportunities to practice (especially if carryover from one day to next doesn't happen)

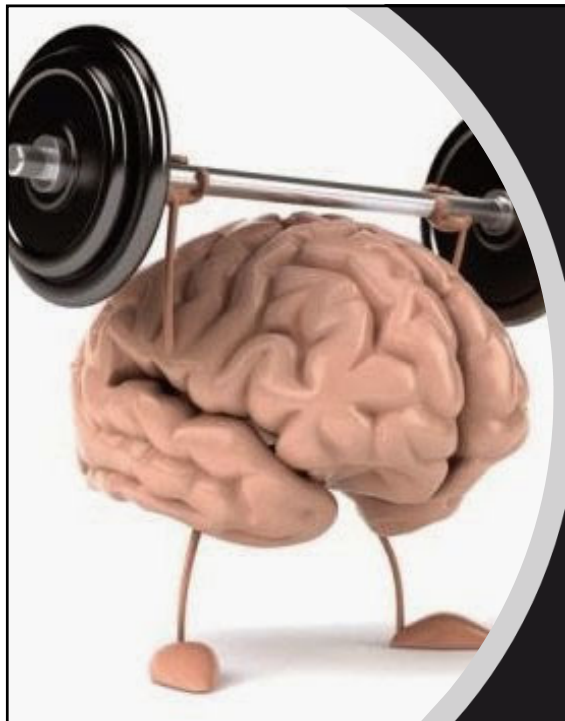
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*Myth #7*  
GROWTH  
MINDSET  
INTERVENTIONS  
INCREASE  
MATH  
PERFORMANCE

Growth  
Mindset



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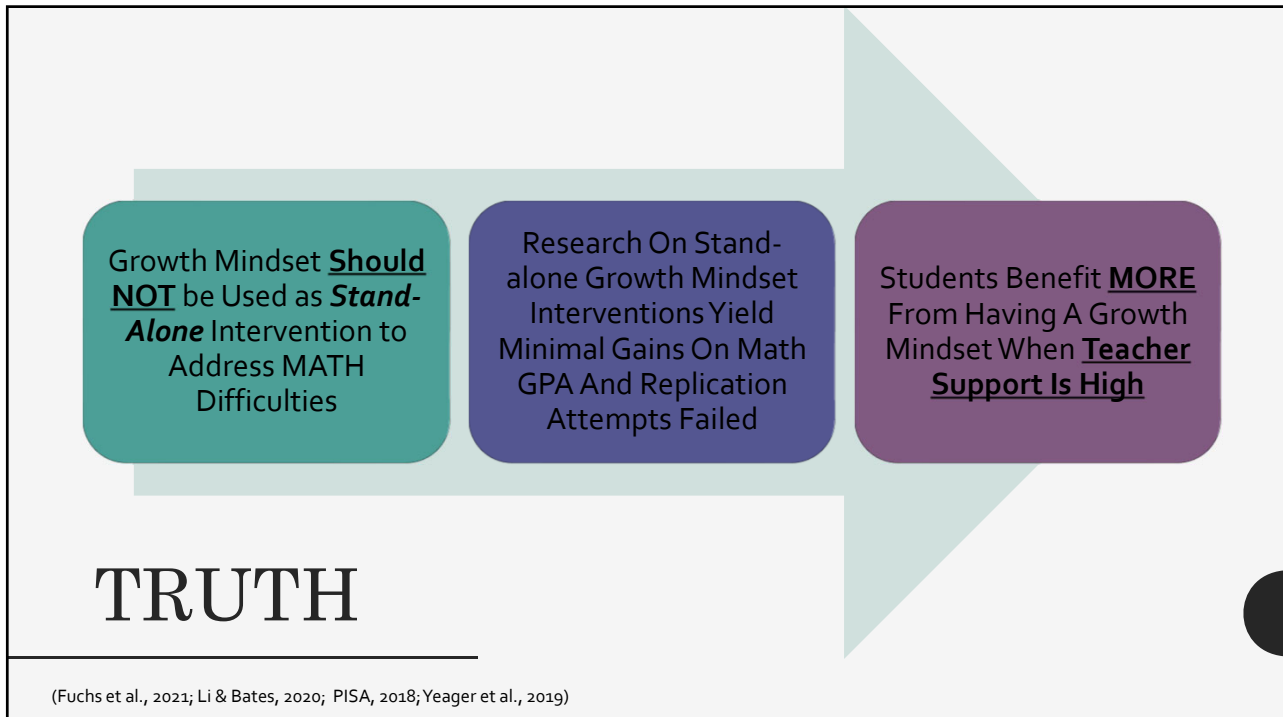


Students from OECD countries scored 23 points higher in math if reported having a growth mindset (PISA, 2018)

↓

2/3 of students world-wide reported having a growth mindset

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Growth Mindset **Should NOT** be Used as **Stand-Alone** Intervention to Address MATH Difficulties

Research On Stand-alone Growth Mindset Interventions Yield Minimal Gains On Math GPA And Replication Attempts Failed

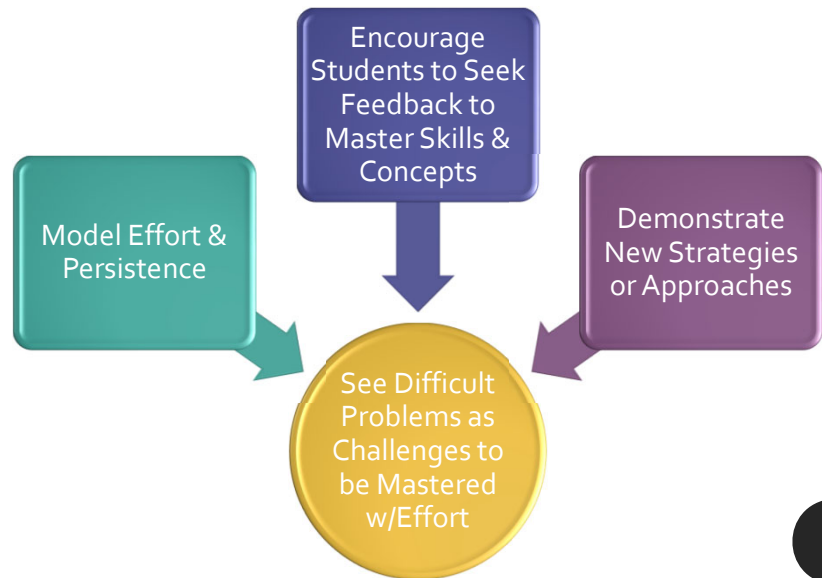
Students Benefit **MORE** From Having A Growth Mindset When **Teacher Support Is High**

# TRUTH

(Fuchs et al., 2021; Li & Bates, 2020; PISA, 2018; Yeager et al., 2019)

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## Encourage Growth Mindset in the Classroom by Supporting Students to...

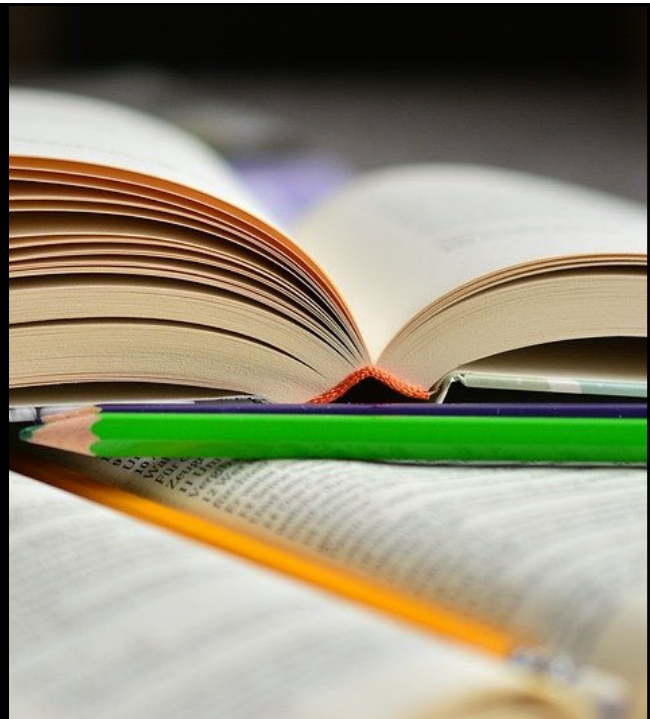


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## SELF-REGULATION

Help students become aware of how they think when problem solving

Use of Heuristics & Mnemonics & Verbalization to teach students how to PLAN, MONITOR, & MODIFY their work



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# Teaching Heuristics



## Understand the Problem

Restate In Own Words  
Break It Down Into  
Smaller Parts  
Draw A Picture/Act It Out  
Use Manipulatives Or  
Visuals



## Devise a Plan

Make a table  
Draw a diagram  
Translate into an equation



## Carry out the Plan



## Look Back (check results)

Put Results In Words  
Does The Answer Address  
The Question?

(Zrebiec Uberti,, Mastropieri & Scruggs, 2004)

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# SELF-MONITORING CHECKLIST



**Read:** Read the problem.



**Ask:** What is the problem asking?



**Draw:** Draw a picture.



**Check:** Does my drawing match the problem?



**Solve:** Solve it!

## Creating A Checklist:

- Individualize
- Include Common Errors
- List Appropriate Step for Error Prevention

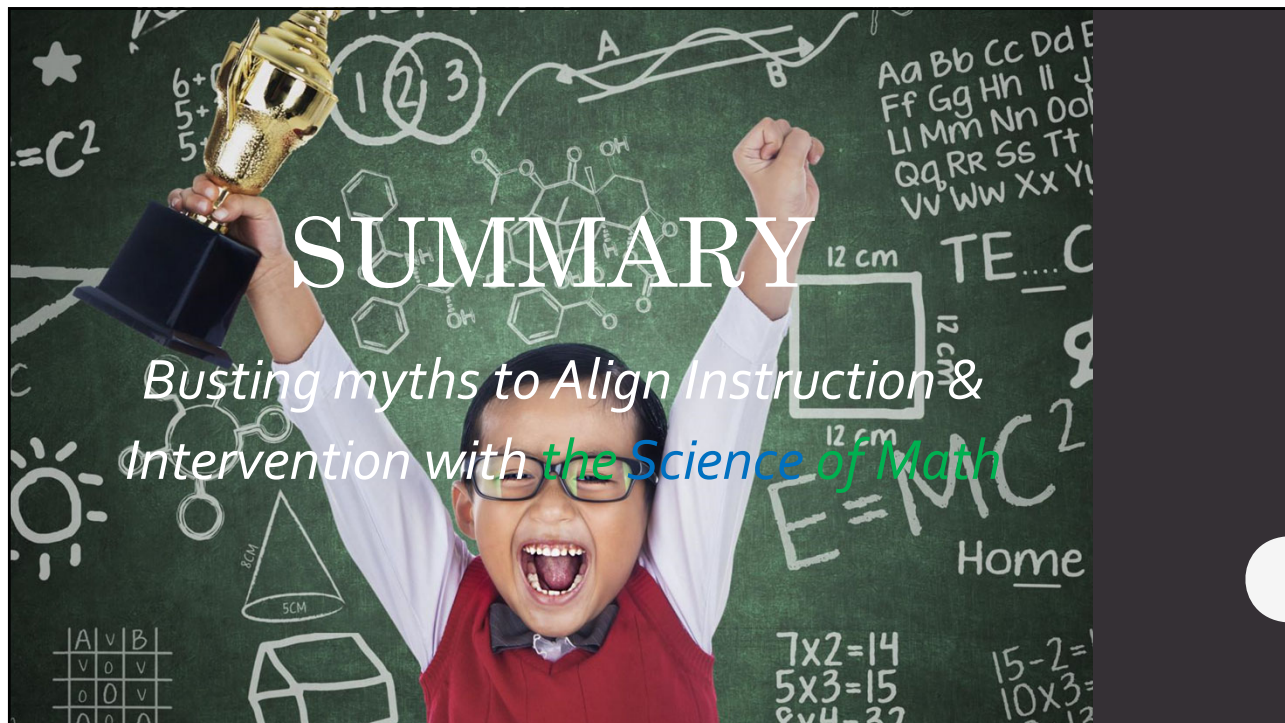
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## Layer Self-Regulation & Motivation Components Into Skill-building


- Praise Effort & Persistence
- Establish Short-Term Learning Goals
- Offer Opportunities for Reflection
- Teach Students to Monitor Their Own Progress Toward Individualized Learning Goals
- Show Students How to Record Learning Accomplishments
- Encourage Students to Check their Work

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Interleave	conceptual understanding & procedural knowledge in every lesson
Teach	the standard algorithm
Challenge	students with novel problems after they've demonstrated accuracy, fluency, generalization with key skills & concepts
Use	explicit systematic instruction everyday & at all tiers (including core instruction)
Assess	For mastery of key pre-requisite skills
Individualize	math interventions when needed
Show	Students how to engage in their own learning



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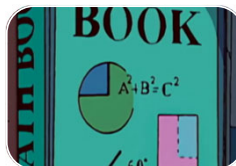
## How Did We Get Here?



Pseudoscience is Seductive



Reform Efforts Left Behind Proven Practices



Limited tSOM Examples Included in Textbooks



Overload of information on the internet and via social media



Implementation Challenges

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Often its Not  
the  
Strategy...It's  
the  
Application

IES WWC What Works Clearinghouse

SEARCH MENU

**PRACTICE GUIDE**

Assisting Students Struggling with Mathematics:  
Intervention in the Elementary Grades

Released: March 2021  
PDF (1.9 MB)

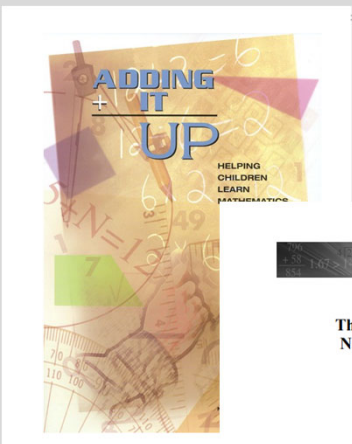
Recommendations Details Panel

**6** Timed Activities: Regularly include timed activities as one way to build fluency in mathematics.

**STRONG EVIDENCE**

**TIER 1 STRONG**

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**Adding It Up**  
HELPING CHILDREN LEARN MATHEMATICS

**Success**

**The Final Report of the  
National Mathematics  
Advisory Panel**

**2008  
U.S. Department of Education**

IES WWC What Works Clearinghouse

SEARCH MENU

- Assisting Students Struggling with Mathematics**  
This practice guide provides evidence-based practices that can help teachers tailor their instructional approaches and/or their mathematics intervention programs to meet the needs of their students.  
Practice Guide | March 2021
- Improving Algebra Knowledge & Strategies in Grades 6-12**  
This practice guide provides three recommendations for teaching algebra to students in middle school and high school. Each recommendation includes implementation steps and solutions for common roadblocks. The recommendations also...  
Practice Guide | April 2015 (Revised January 2018)  
**Related Resource (2.7 MB)**  
This six-page practice guide summary provides an overview of the three recommendations for teaching algebra to students in middle school and high school. See the research evidence at a glance.  
Practice Guide Summary | July 2015
- Teaching Math to Young Children**  
This practice guide provides five recommendations for teaching math to children in preschool, prekindergarten, and kindergarten. Each recommendation includes implementation steps and solutions for common roadblocks. The recommendations also...  
Practice Guide | November 2013  
**Related Resource (883 KB)**  
This eight-page summary reviews expert recommendations from the field, along with tips on implementing them. See the research evidence at a glance.  
Practice Guide Summary | February 2014
- Improving Math Problem Solving in Grades 4-8**  
This practice guide provides five recommendations for improving students' mathematical problem solving in grades 4 through 8. This guide is geared toward teachers, math coaches, other educators, and curriculum developers who want to...  
Practice Guide | May 2012 (Revised October 2018)  
**Related Resource (925 KB)**  
This eight-page set of instructional tips translates practice guide recommendations into actionable approaches that educators can try in their classrooms.  
Instructional Tips | July 2017
- Developing Fractions Instruction for K-8**  
This practice guide presents five recommendations intended to help educators improve students' understanding of fractions. Recommendations include strategies to develop young children's understanding of early fraction concepts...  
Practice Guide | September 2010
- Assisting Students K-8 in Mathematics**  
Taking early action may be key to helping students struggling with mathematics.  
Practice Guide | April 2009
- Encouraging Girls in Math and Science**  
The objective of this guide is to provide teachers with specific recommendations that can be carried out in the classroom without requiring systemic change.

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- What Myth Will you Bust in Your School?
- Why?
- How Will You Bust the Myth?



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**Daniel Willingham—Science & Education**

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**Objections to Jo Boaler's Take on Neuroscience and Math Education**  
3/13/2019

Guest post with [Daniel Ansari](#), Professor and Canada Research Chair in Developmental Cognitive Neuroscience in the Department of Psychology and the Brain & Mind Institute at the University of Western Ontario in London, Ontario, where he heads the [Numerical Cognition Laboratory](#).

On February 28th Stanford Professor Jo Boaler and one of her students, [Tanya Lauer](#), published an article that we think is a fine example of how not to draw educational conclusions from neuroscience data. While we're more interested in applauding great work than pointing out problems, we feel we can't ignore an article in a high profile venue like [Time Magazine](#). The backbone of their piece includes three points:

**THE SCIENCE OF MATH**  
the Science of Math • Math Teaching • Misconceptions in Math • Contributors & Affiliates  
Preorder 2019/20

**Focusing on evidence to improve learning**

**ERIC**  
Collection Thesaurus  
Search education resources  
☐ Peer reviewed only ☐ Full text available on ERIC

**Belief-Based versus Evidence-Based Math Assessment and Instruction**  
VanDerHeyden, Amanda M.; Coddling, Robin S.  
Communique, v48 n5 p1, 20-25 Jan-Feb 2020


Many school psychologists work in schools that have low proficiency rates on the year-end test of mathematics, which is concerning because math proficiency is a powerful indicator of long-term academic success. Addressing math instructional problems is not easy work. One reason the authors examine is that the work is so challenging for school psychologists is that there is a great deal of philosophy that is at odds with contemporary evidence, yet is embraced by the teachers, school coaches, and leaders who observe the large and persistent achievement gaps, care deeply about their students, and want to avoid harm. The result is tension between evidence-based and philosophy-based practices in math education. In the rest of this paper, they will discuss some common misunderstandings of math practices and summarize available evidence that school psychologists may use to advise systems in the thoughtful implementation of evidence-based practices in ways that bring mathematical success to more children.

# If you Want to Know More...

**THE CENTRAL ILLUSION INDEPENDENT STUDIES**  
ABOUT • COMMENTARY • PEOPLE • EVENTS • SUPPORT • CONNECT •  
intergenerational • scientific • standard • cultural society • religious • language • other

**Myths That Undermine Maths Teaching**  
Lauri S. Kover, University of Minnesota

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*BUSTING MYTHS TO  
ALIGN INSTRUCTION &  
INTERVENTION WITH  
THE SCIENCE OF MATH*

