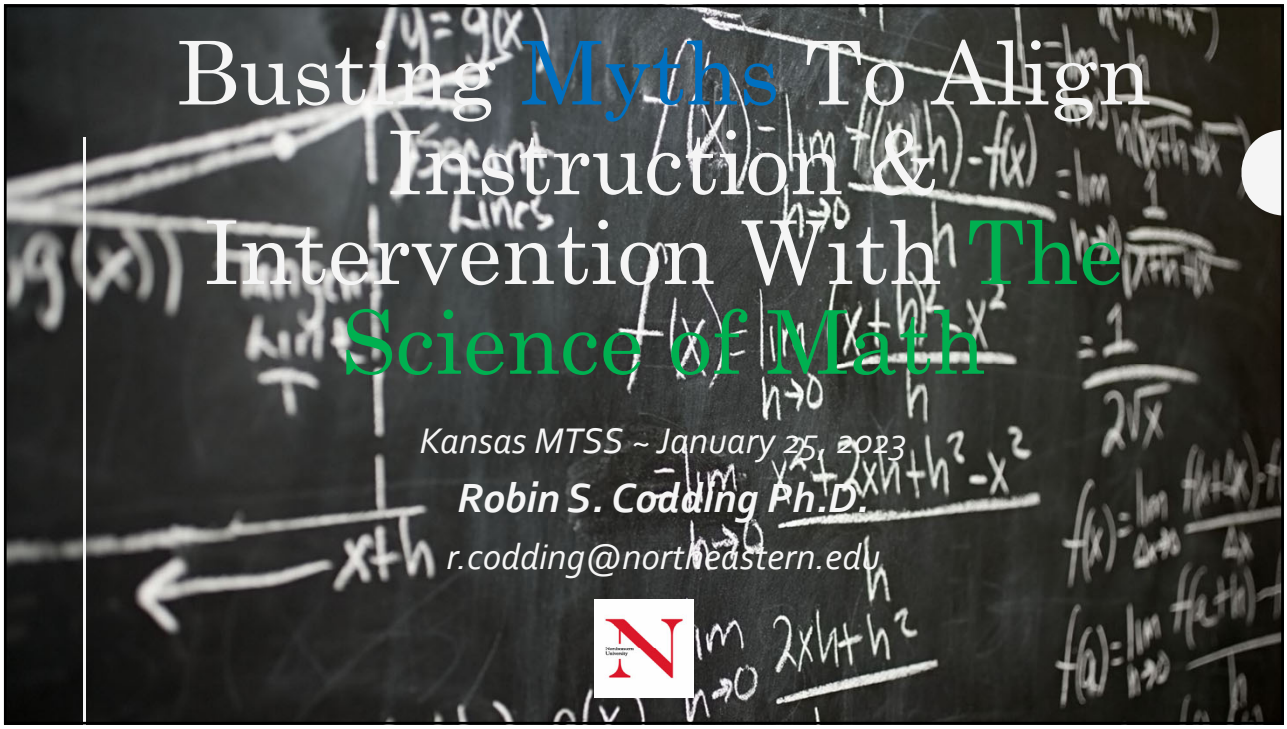


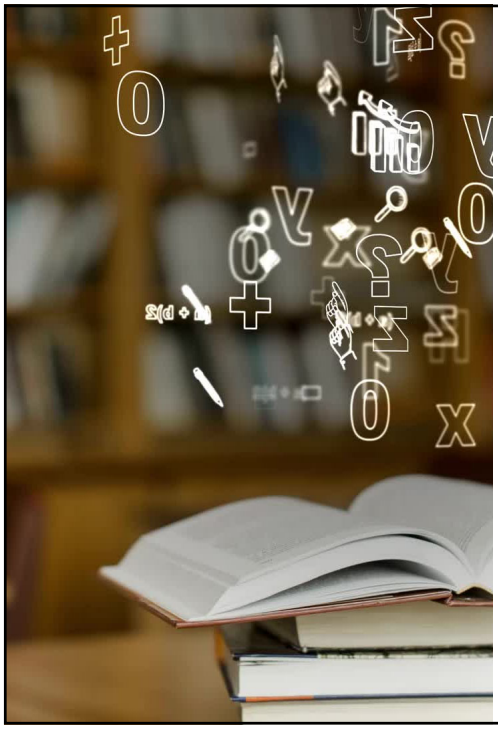
1

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

2



Overview

1. Teach Conceptual Knowledge 1st
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

3

4

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)

5

8/10 + 6/10 = x

- Solve problems in a familiar format

2 ½ + ¼ = x

- Solve problem with a new surface or problem feature

5 + 4 =

- Quick and effortless recall of basic facts

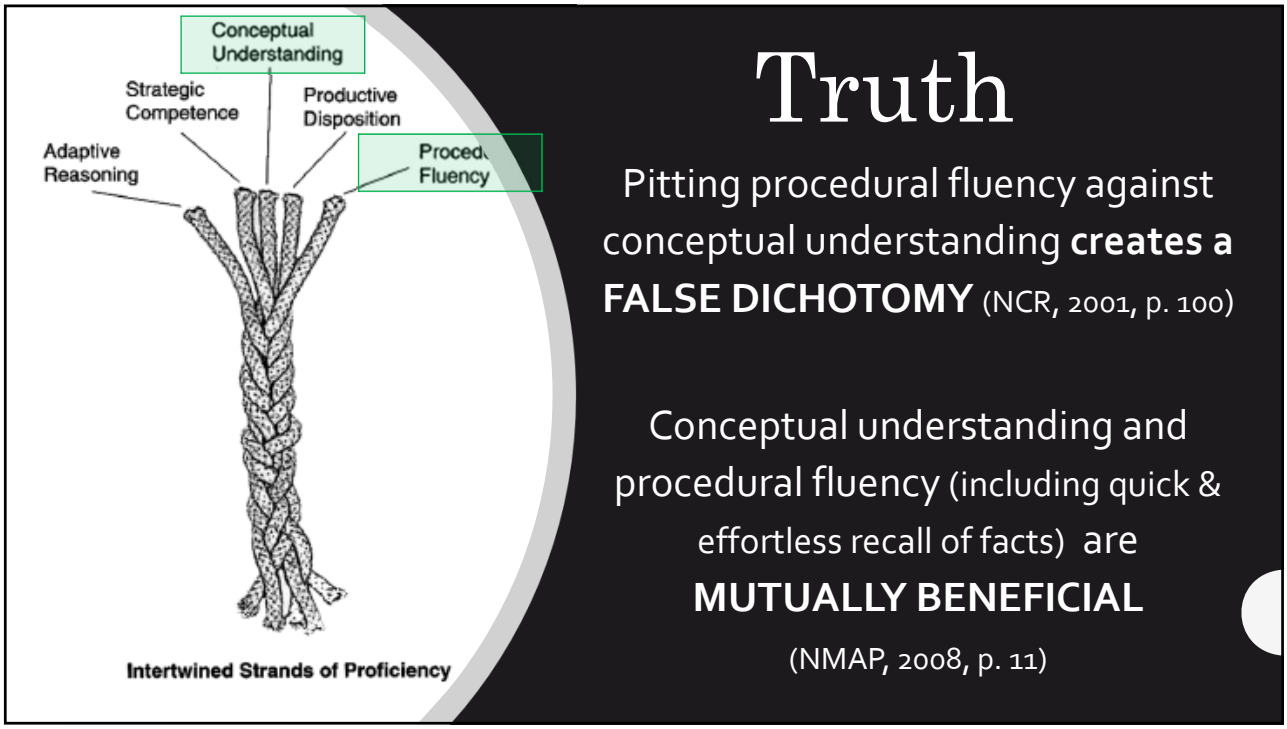
58 + 62 =

- 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)

6



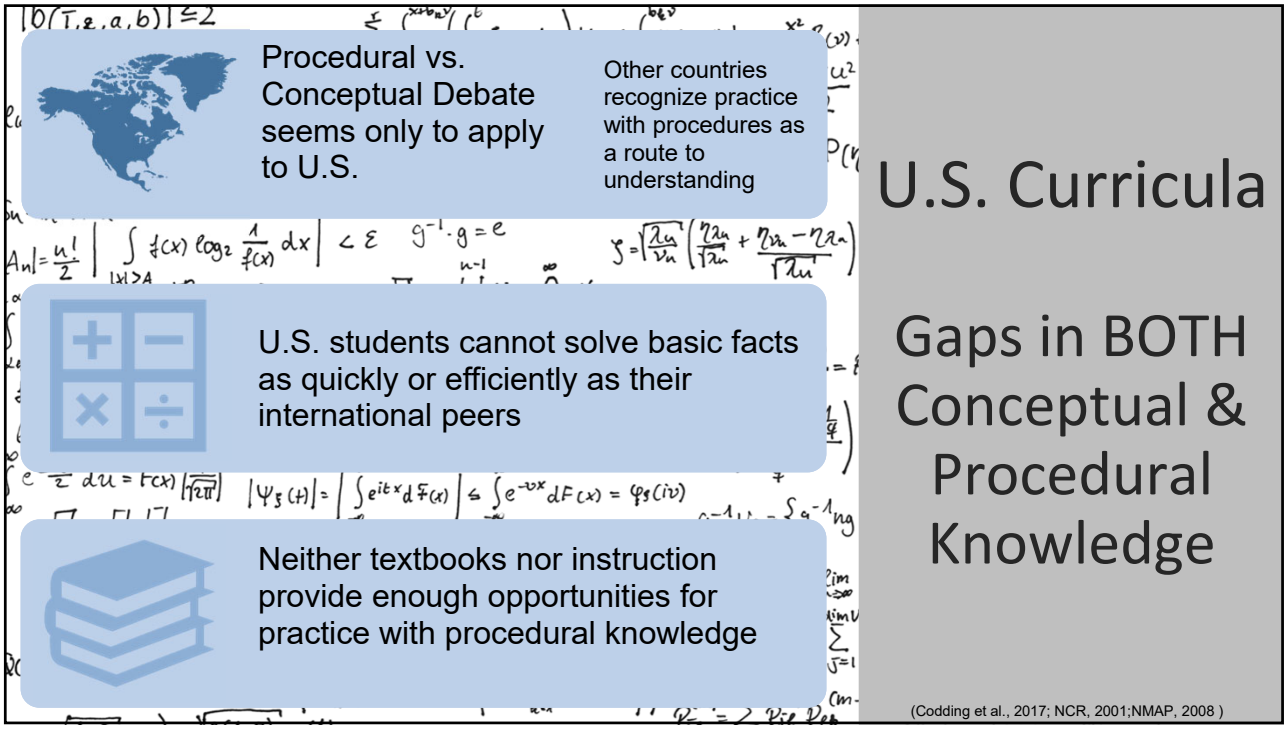
Truth

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)

7



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

Other countries recognize practice with procedures as a route to understanding

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

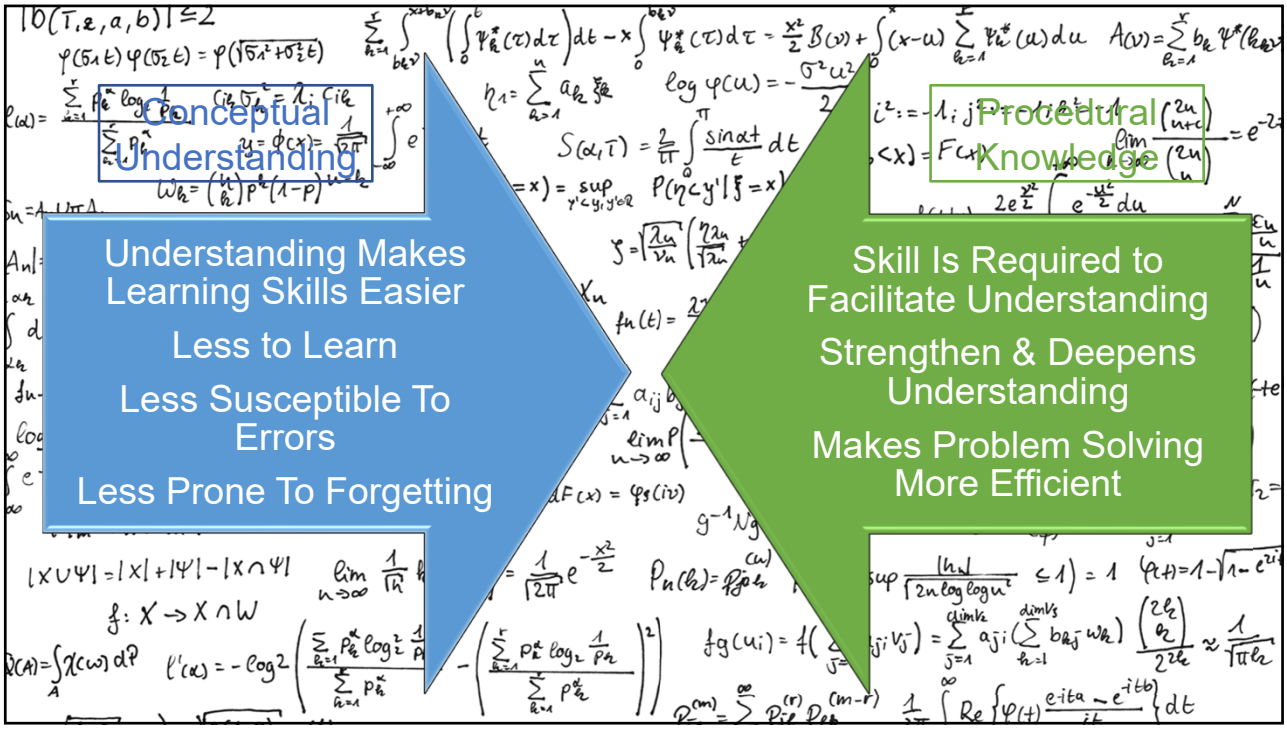
Neither textbooks nor instruction provide enough opportunities for practice with procedural knowledge

U.S. Curricula

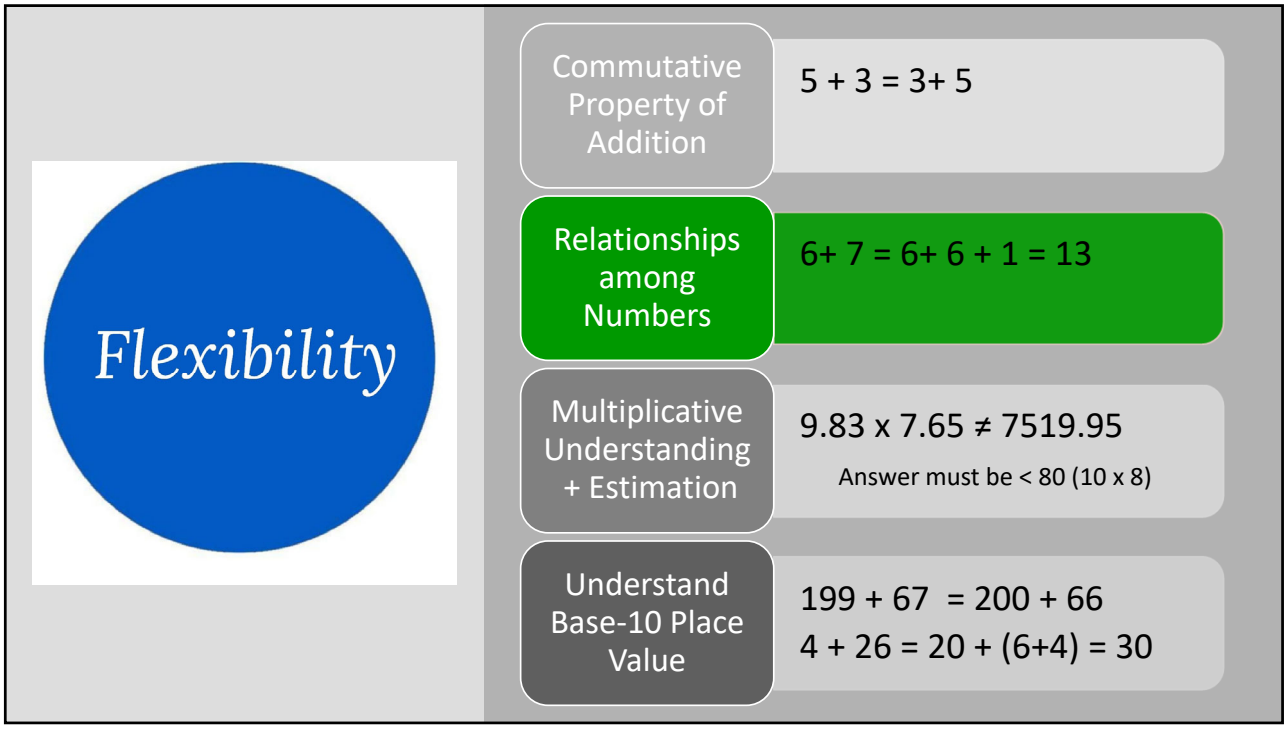
Gaps in BOTH Conceptual & Procedural Knowledge

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

8


Conceptual Understanding
Understanding Makes Learning Skills Easier
Less to Learn
Less Susceptible To Errors
Less Prone To Forgetting
Procedural Knowledge
Skill Is Required to Facilitate Understanding
Strengthen & Deepens Understanding
Makes Problem Solving More Efficient

9


Flexibility
Commutative Property of Addition
5 + 3 = 3+ 5
Relationships among Numbers
6+ 7 = 6+ 6 + 1 = 13
Multiplicative Understanding + Estimation
9.83 x 7.65 ≠ 7519.95
Answer must be < 80 (10 x 8)
Understand Base-10 Place Value
199 + 67 = 200 + 66
4 + 26 = 20 + (6+4) = 30

10

Theories Regarding the Relationship Between Conceptual Understanding & Procedural Fluency

Concepts-first
Conceptual basis is necessary to execute procedures

Procedures-first
Procedures are learned via modeling and concepts are extrapolated

Iterative
The learning of one (concepts or procedures) improves the other

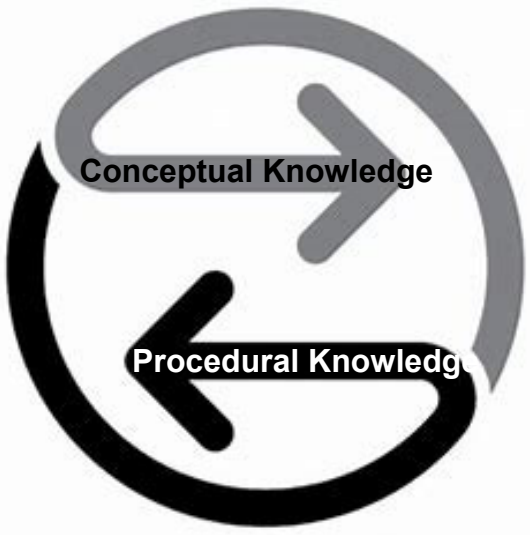
Simultaneous
Concepts and procedures are inextricably linked, and therefore develop synchronously

Empirical studies have shown a *bidirectional* relationship between concepts and procedures

(Baroody, 2003)

11

EVIDENCE



- Counting (preschoolers)
- Decimals (middle schoolers)
- Addition & Subtraction (primary schoolers)
- Equivalence (primary schoolers)
- Fractions (primary schoolers)

(Canobi, 2009; Hecht & Vagi, 2010; Rittle-Johnson & Koedinger, 2009; Rittle-Johnson et al., 2001, 2015; Running, Codeling et al., in press; Schneider et al., 2011)

12

Best Practices

Interleave conceptual and procedural content within lessons

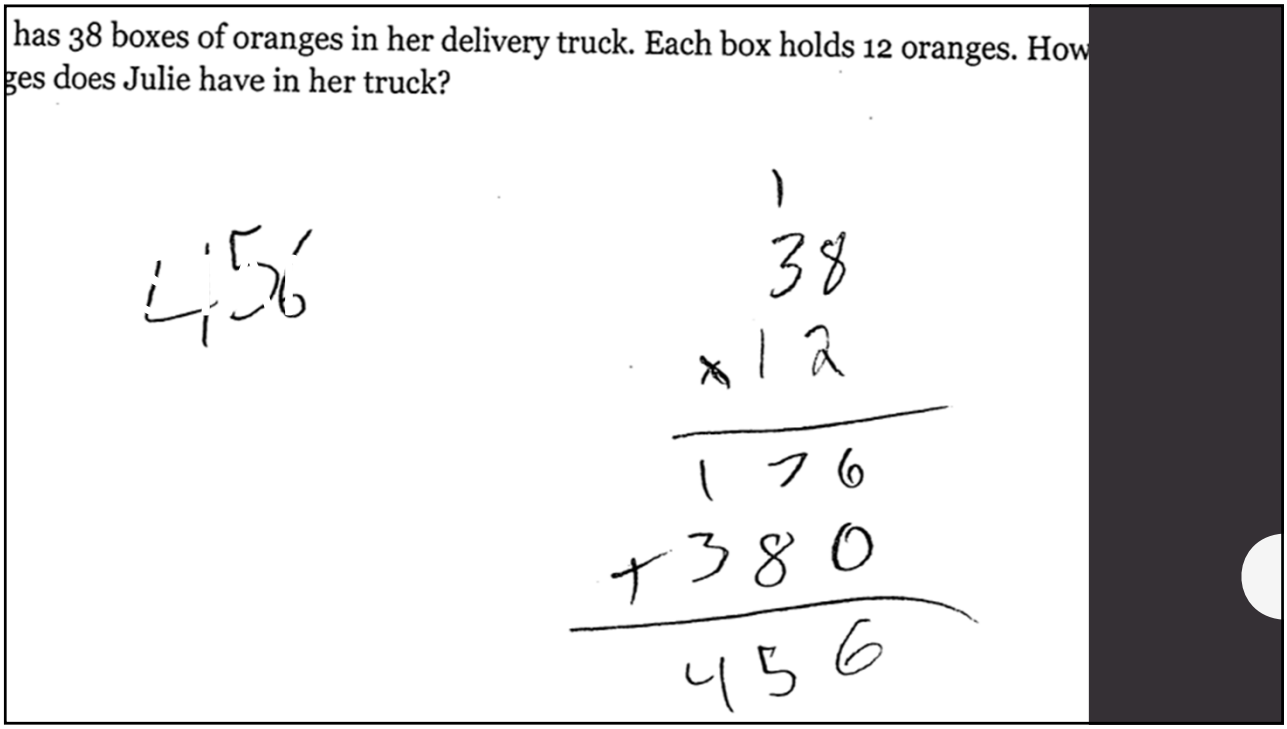
13

MYTH #1 HAS LED TO THESE OTHER MYTHS:

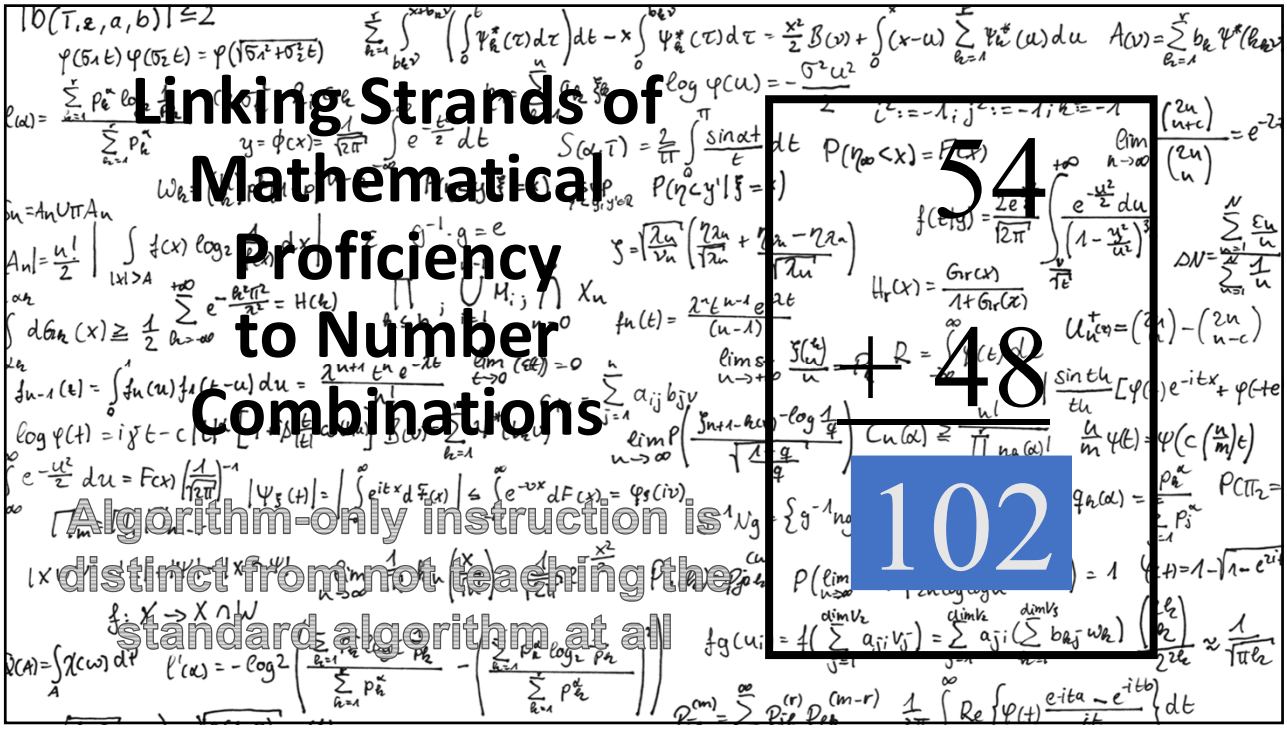
Standard Algorithms are Harmful

Fact Fluency Doesn't Matter

14


has 38 boxes of oranges in her delivery truck. Each box holds 12 oranges. How
ges does Julie have in her truck?
456
38
×12
76
+380
456

15


Linking Strands of Mathematical Proficiency to Number Combinations
54
+48
102
Algorithm-only instruction is distinct from not teaching the standard algorithm at all

16

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

   1
   54
   +48
   10 2
3. Sum the digits in the tens column

1. 48 = 4 10 & 8 ones
2. Add the 4 10 to 54
   64→74→84→94
3. Add 8 ones to 94

17

Truth

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

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

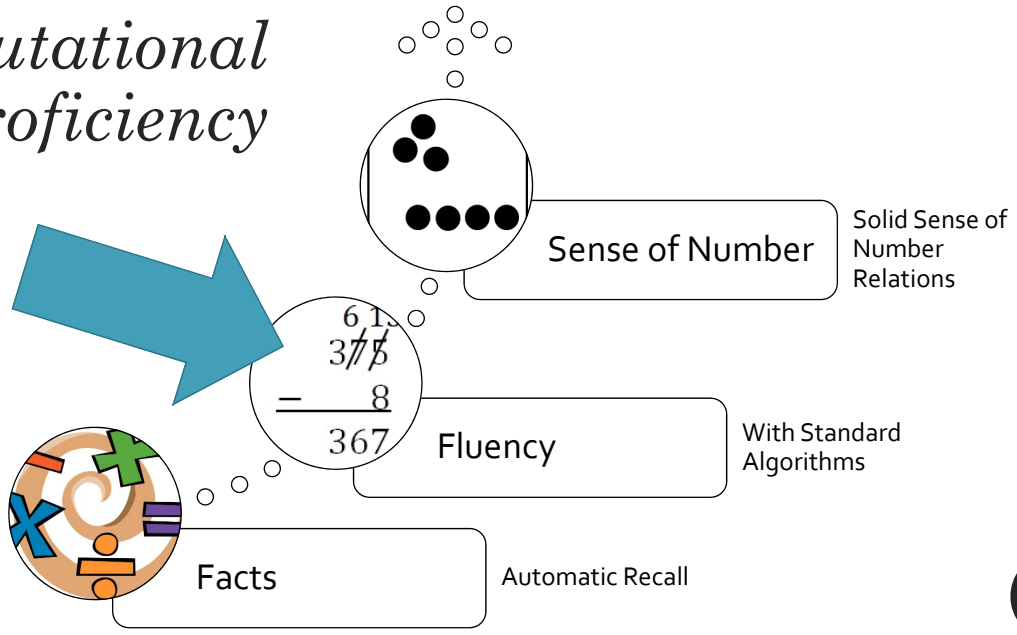
18

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)

19

Computational Proficiency



(National Mathematics Advisory Panel, 2008)

20

BEST PRACTICES

Help Students Understand When to Use & Why

Teach the Standard Algorithm

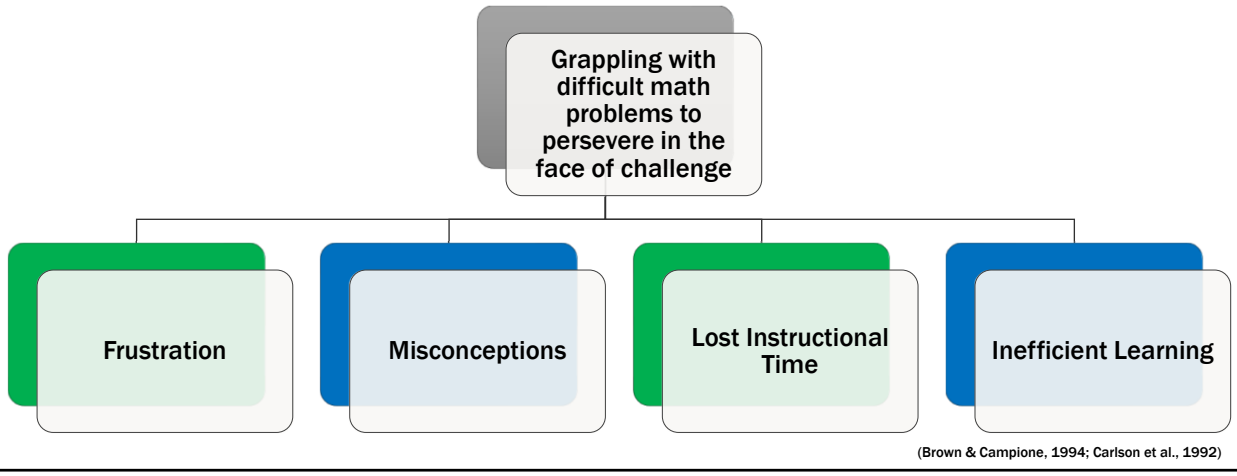
21

Myth #3

PRODUCTIVE STRUGGLE LEADS TO DEEPER LEARNING

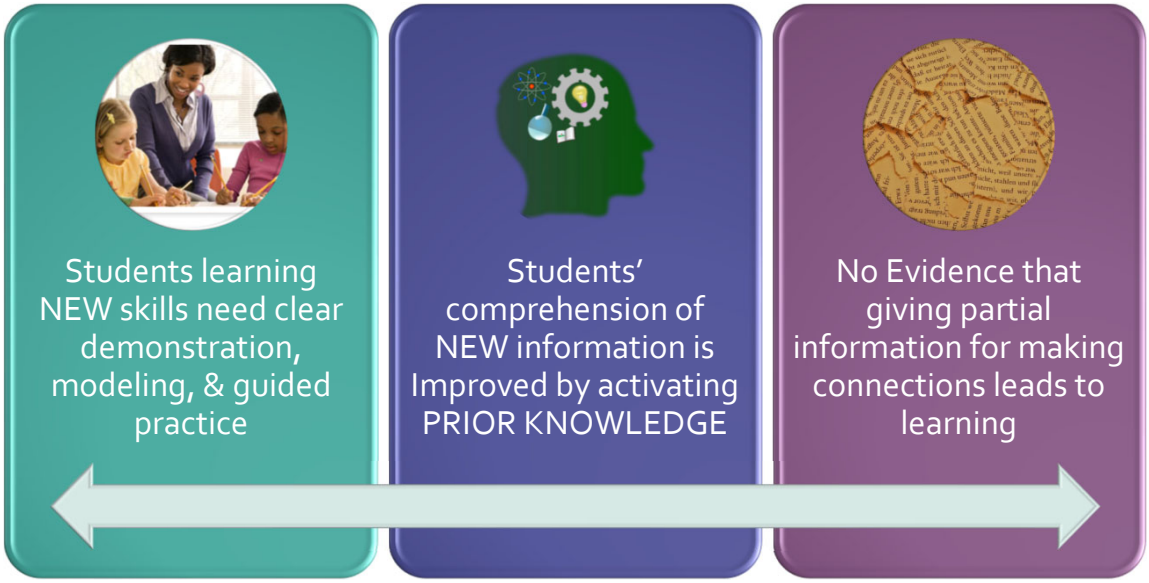
22

PRODUCTIVE STRUGGLE



(Brown & Campione, 1994; Carlson et al., 1992)

23



(Iris Center: https://iris.peabody.vanderbilt.edu/module/sec-rdng/cresource/q3/p09/; Kirschner et al., 2010; Kirschner & Hendrick, 2020)

24

Instructional Hierarchy

(Burns et al., 2010; Codding 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

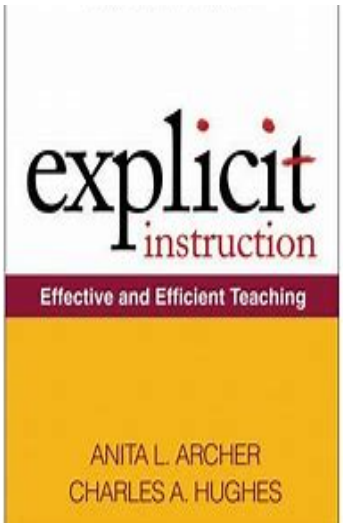
APPLYING – Skills & Concepts are Integrated and Applied to Novel Problems

25

Best Practices

Scaffold	Build on	Provide
Scaffold Learning According to the Instructional Hierarchy	Build on Prior Knowledge	Provide Challenging Problems After Students Demonstrate Accuracy, Fluency, & Generalization w/Required Skills & Concepts

26



Myth #4

EXPLICIT INSTRUCTION IS ONLY HELPFUL FOR SOME STUDENTS

27

Explicit Instruction

Systema[illegible]

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

[illegible]ing
[illegible]al concepts
[illegible]d skills (Doabler et al., 2014; Carnine et al., 2004)

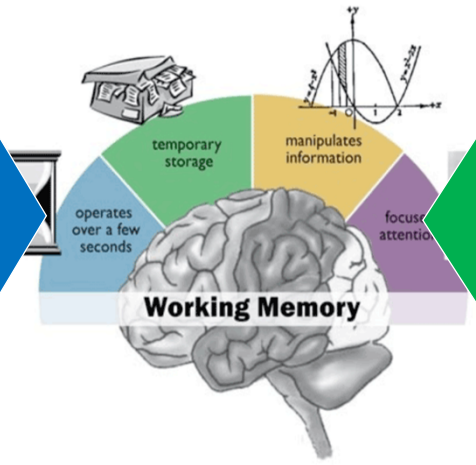
- Teacher-Directed

28

28

SCIENCE OF LEARNING

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



Working Memory (WM) is Limited in Duration & Capacity

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

29

Challenges Working Memory & Hampers Learning

Explicit Instruction is Better for Novices & Students with or at-risk for SLD Math

Discovery Instruction Better for Experts & Less Empirical Support

Works w/ Working Memory Constraints Facilitates Efficient & Effective Learning

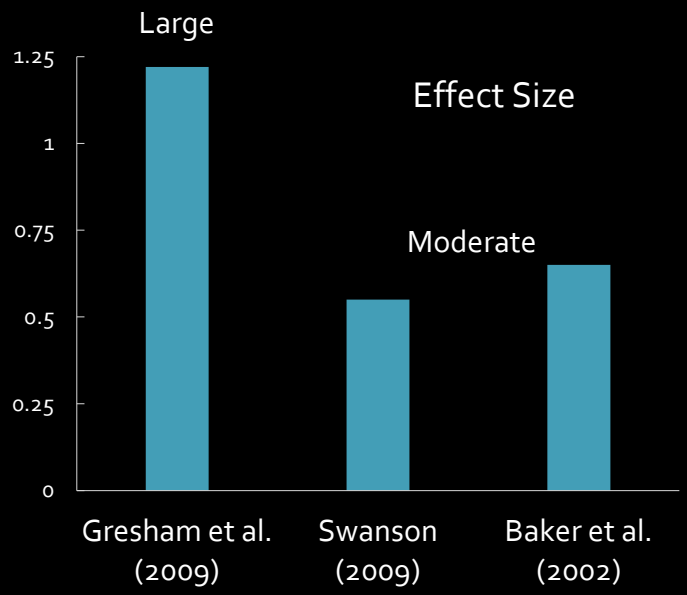
(Kirschner & Hendrick, 2020)

30

Evidence

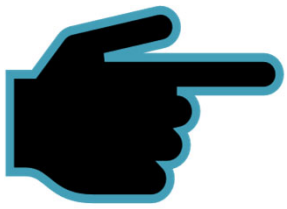
Students with math difficulties & disabilities **BENEFIT MORE** from explicit instruction than discovery-oriented methods

(Kroesbergen & Van Luit, 2003)



31

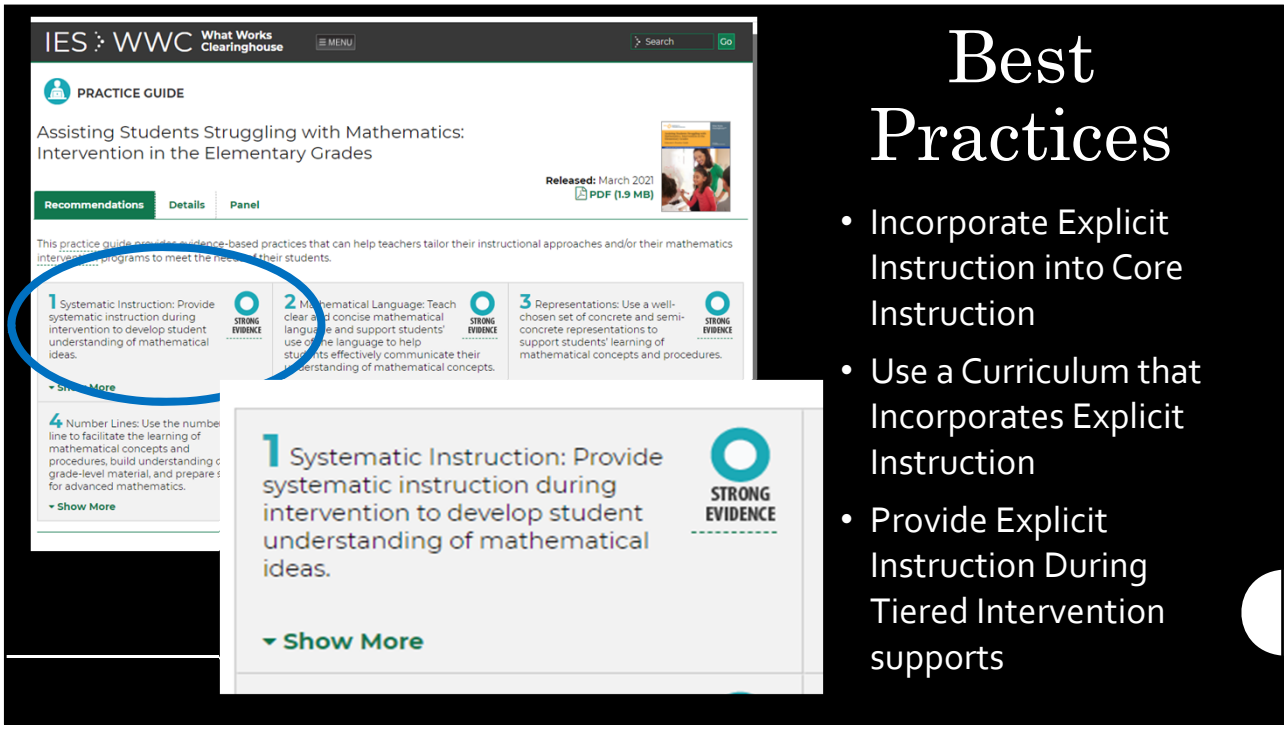
Truth



- 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)

32



Best Practices

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

33

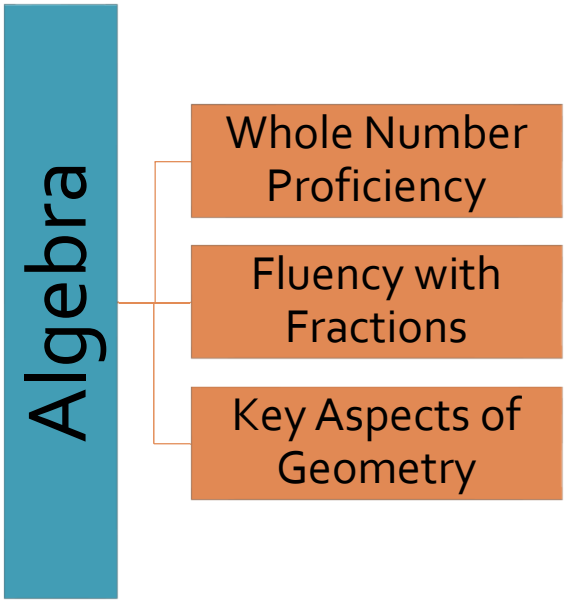
34

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

35

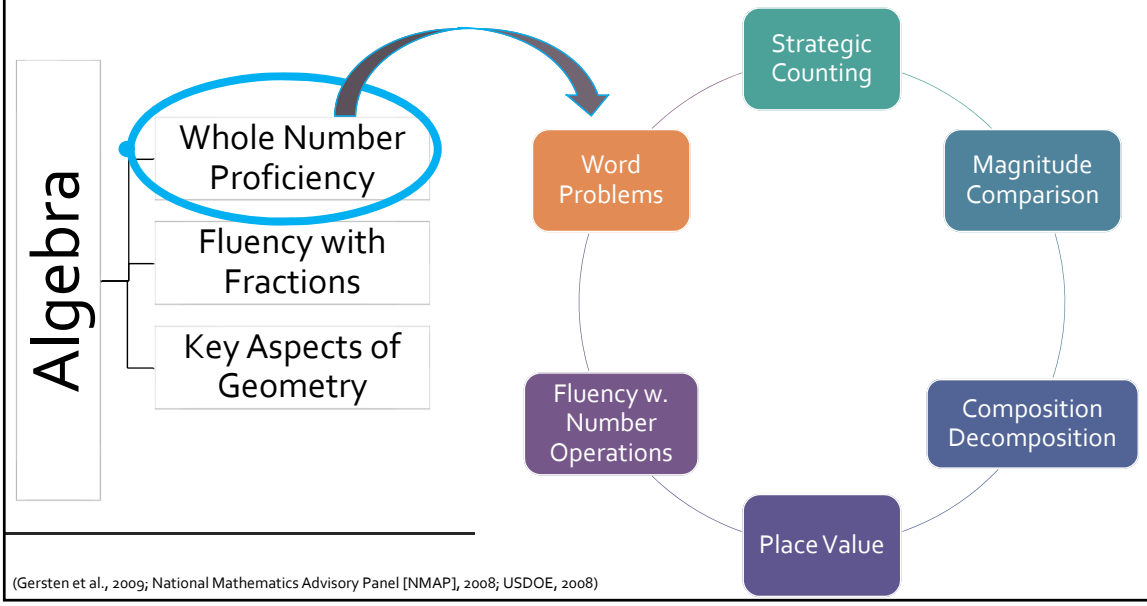
Critical Foundations for Algebra



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

36

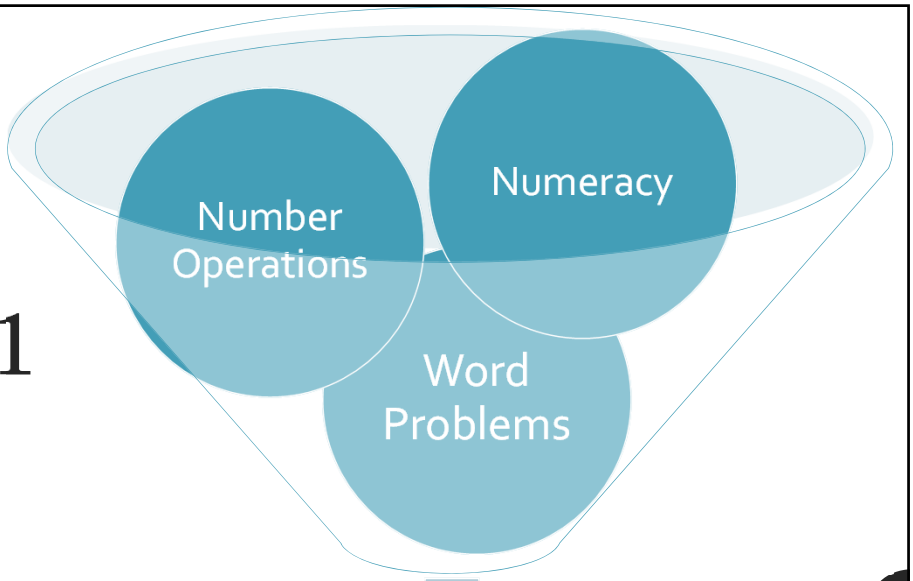
Key Content Targets for Mastery (K-5)



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

37

Bucket 1

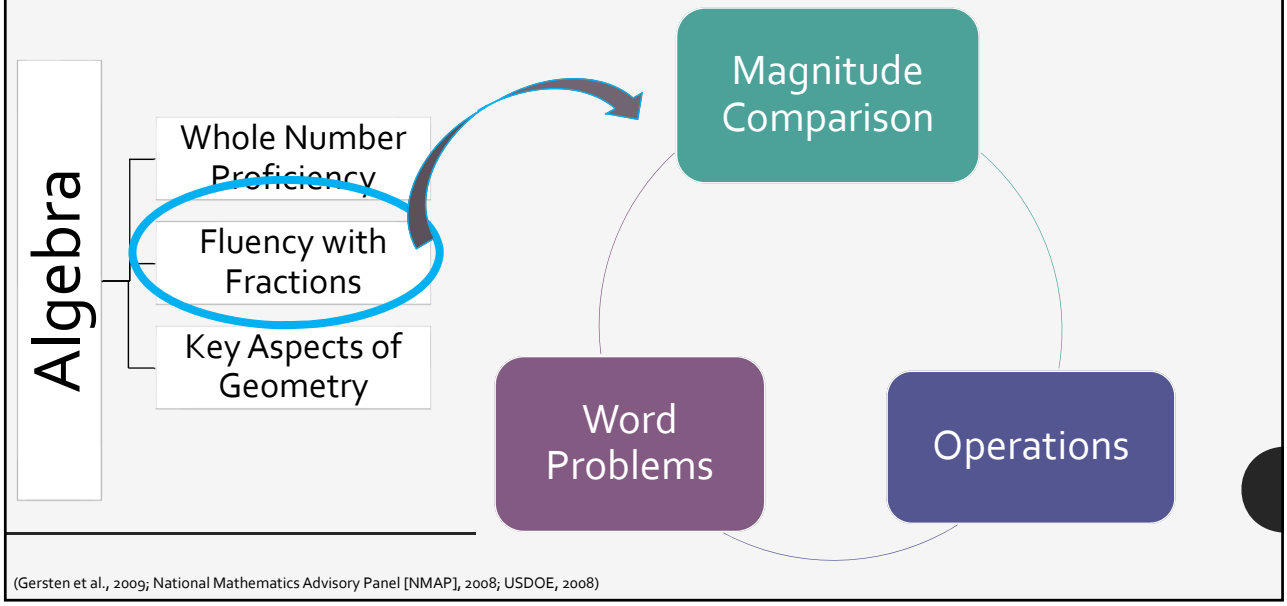


Whole Number Knowledge

National Mathematics Advisory Panel (2008)

38

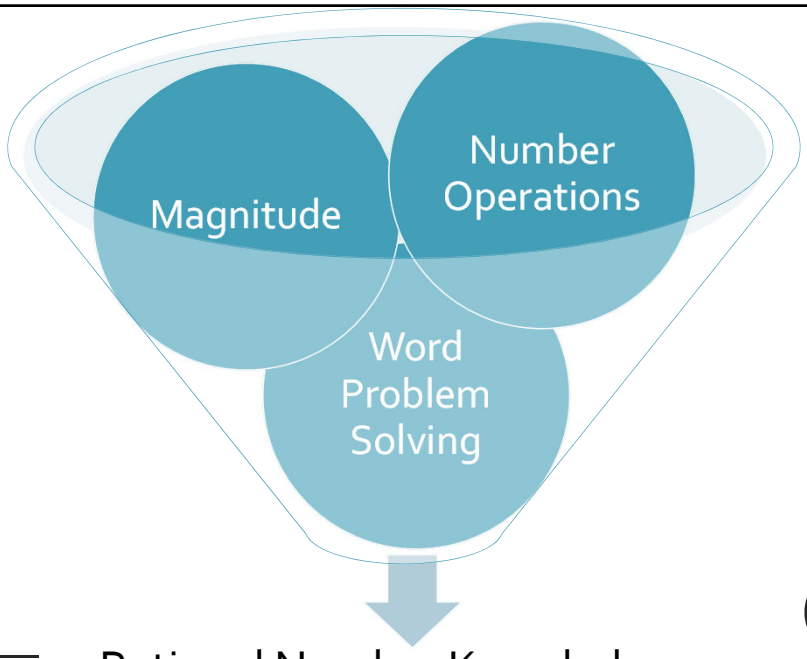
Key Content Targets for Mastery (4-8)



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

39

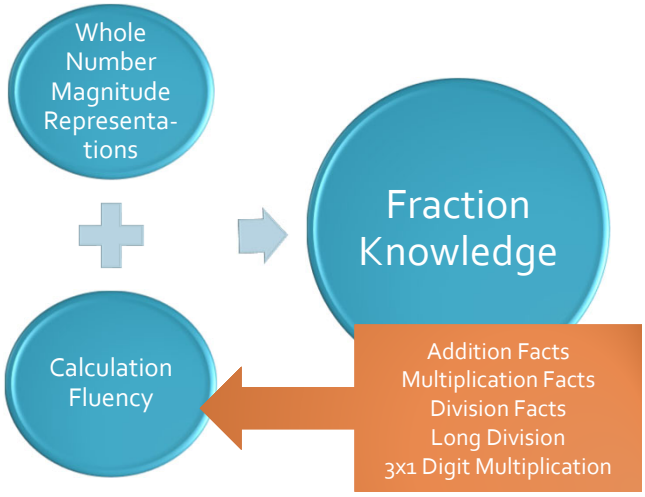
Bucket 2



40

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



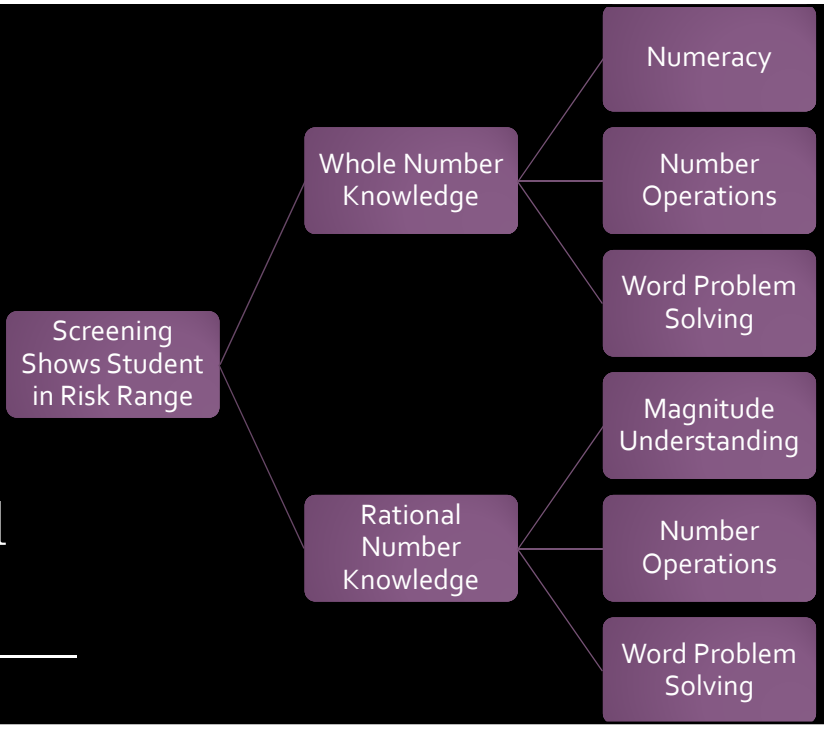
(Hansen, Jordan, & Rodrigues, 2017; Ilyse et al., 2016; Numkung et al., 2018; Resnick et al 2018)

41

Best Practices:

K-8 Emphasis

Teach Foundational Skills 1st



42

Myth #6

EXECUTIVE FUNCTIONING TRAINING MATTERS

43

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

44

Relationship between Achievement & EF

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

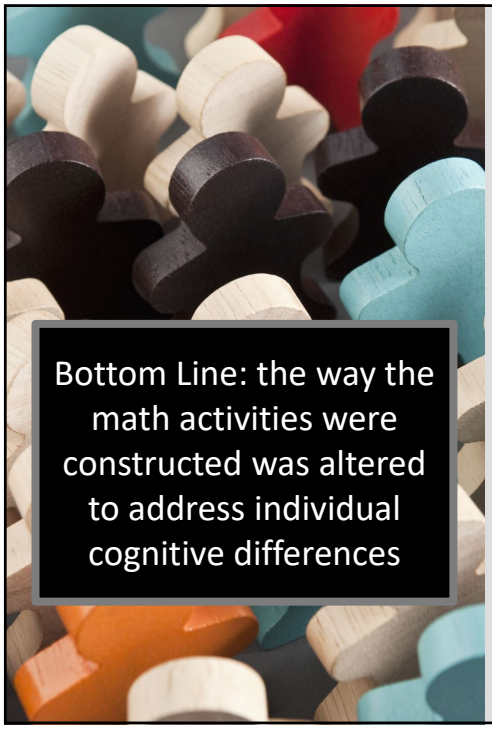
This relationship was reduced when studies controlled for IQ and other background characteristics

Very few rigorous EF training intervention studies exist

EF training interventions improved EF functioning but not academic outcomes

(Jacob & Parkinson, 2015)

45



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

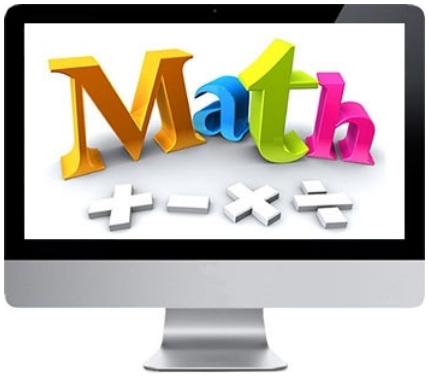
Regardless of cognitive reasoning skills (weak or strong) improvement occurred with fluency building version	For students with weak reasoning ability, the conceptual activity version led to poorer outcomes than students with stronger reasoning ability

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)

46



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

Best Practices

To Individualize Math Interventions

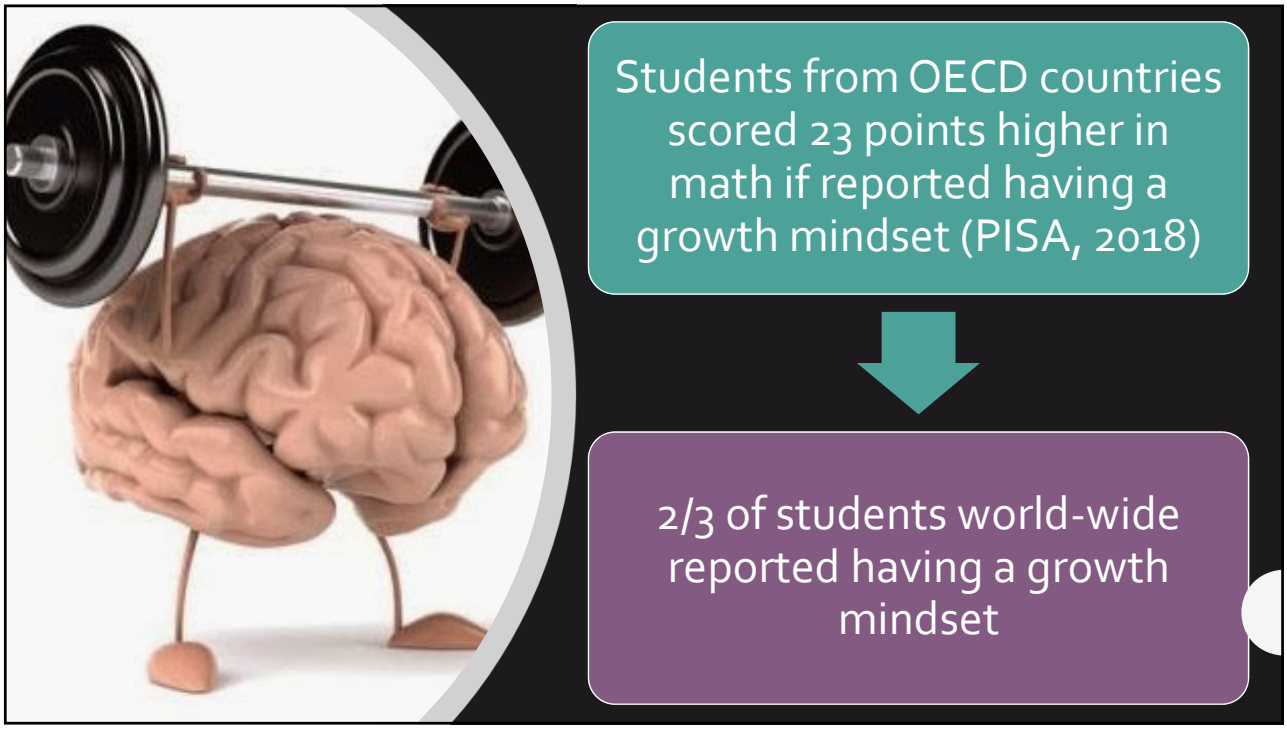
- Minimize cognitive load on working memory and reasoning by
  - *including explicit instruction & breaking down problems into smaller more manageable parts*
- Minizine excessive language load by
  - *using visual and concrete representations and providing fluency practice*
- Increase repetition and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

47

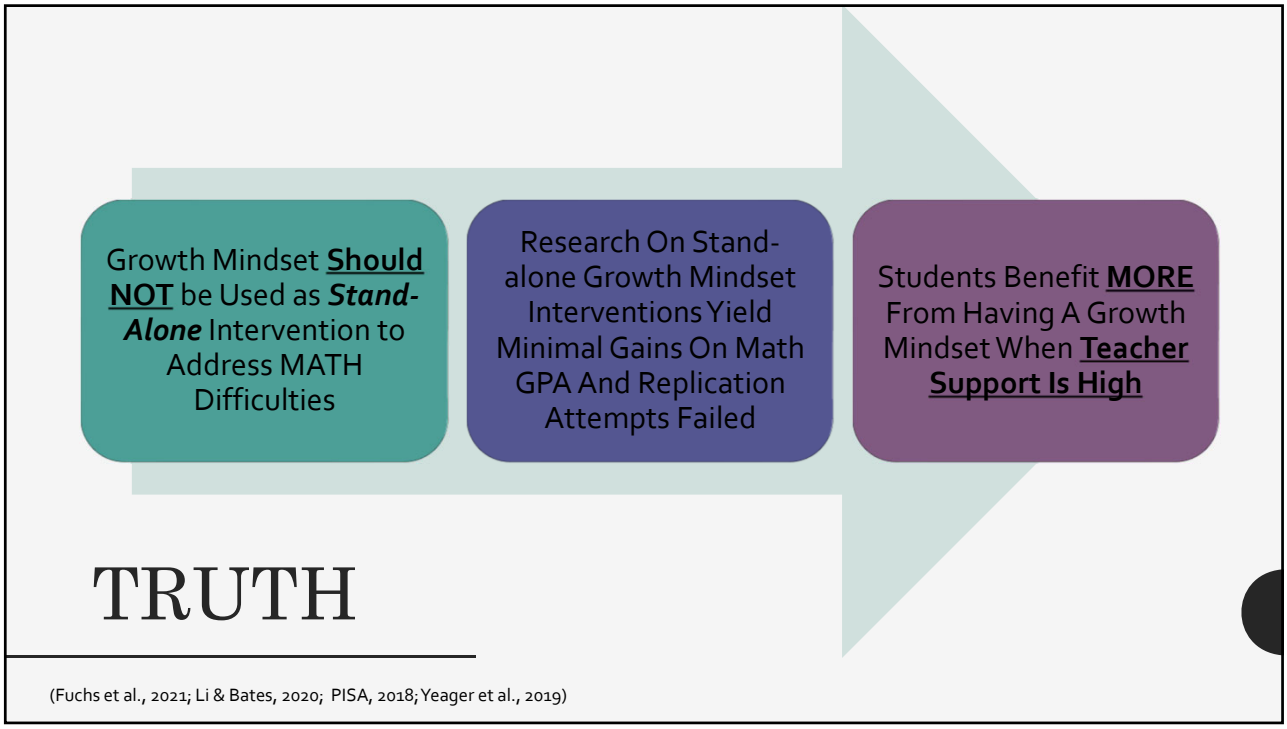
Myth #7

GROWTH MINDSET INTERVENTIONS INCREASE MATH PERFORMANCE

48

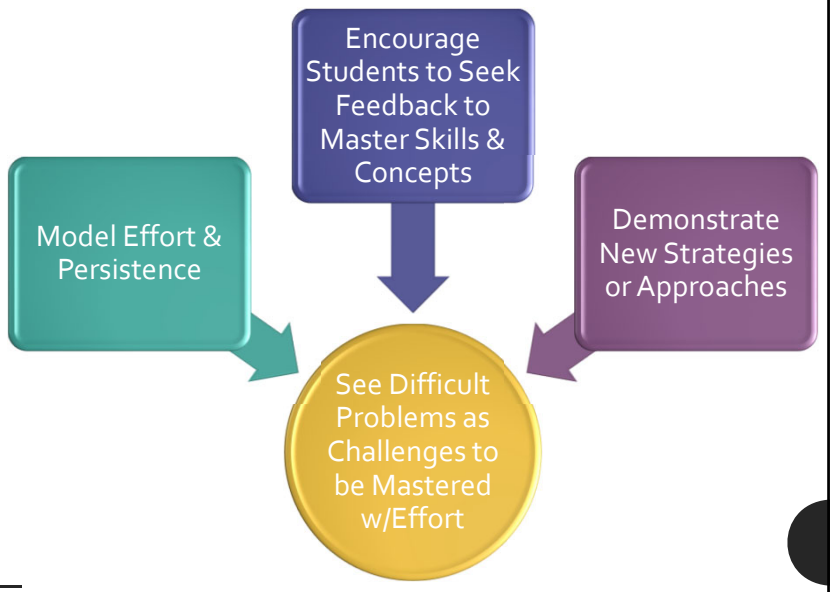

Students from OECD countries scored 23 points higher in math if reported having a growth mindset (PISA, 2018)
2/3 of students world-wide reported having a growth mindset

49


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)

50

Encourage Growth Mindset in the Classroom by Supporting Students to…

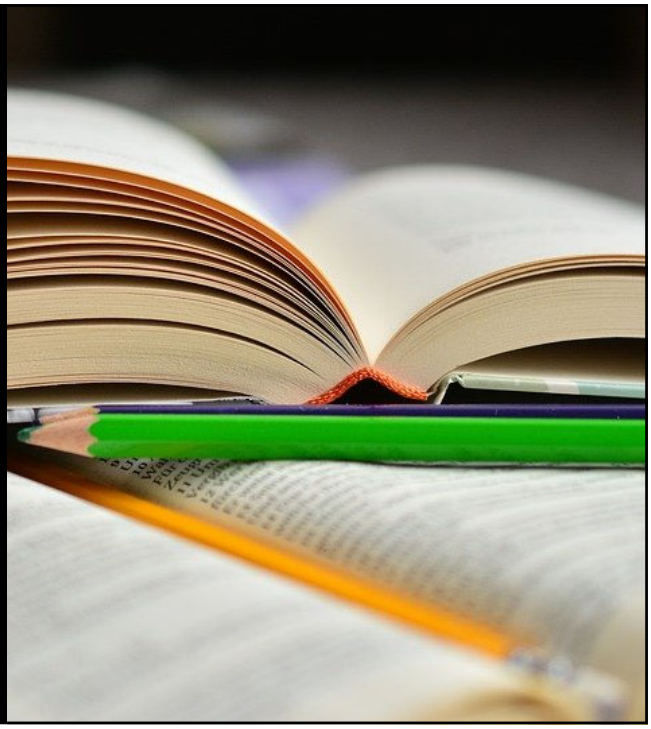


51

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



52

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)

53

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:

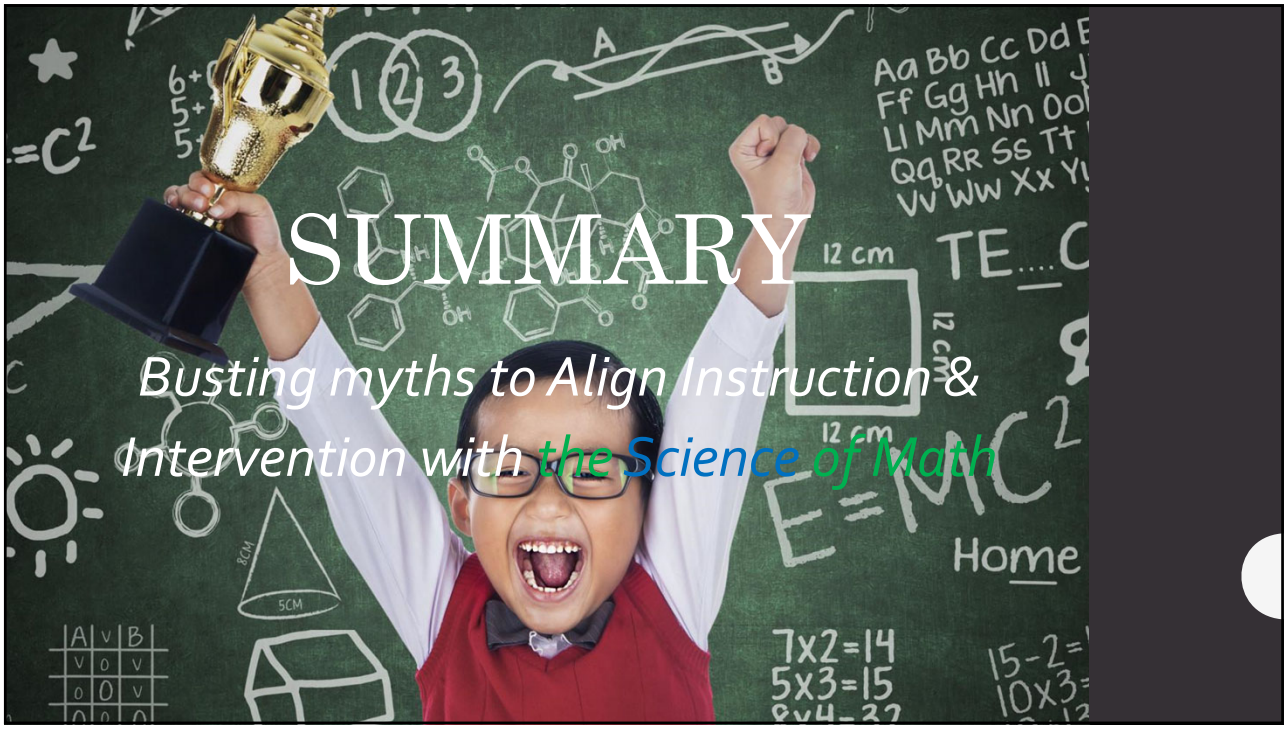
- **Individualize**
- **Include Common Errors**
- **List Appropriate Step for Error Prevention**

54

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

55



56

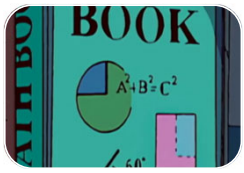
Interleave	conceptual understanding & procedural knowledge in every lesson
Teach	the standard algorithm
Challenge	students with novel problems after they've demonstrated accuracy, fluency, generalization with key skills & concepts
Use	explicit systematic instruction everyday & at all tiers (including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

57

How Did We Get Here?

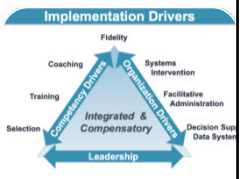
Pseudoscience is Seductive

Reform Efforts Left Behind Proven Practices



Limited tSOM Examples Included in Textbooks

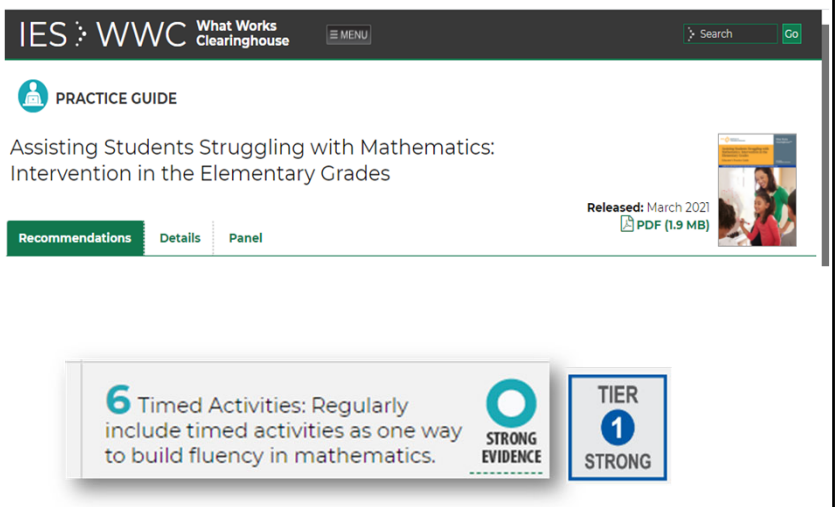
Overload of information on the internet and via social media



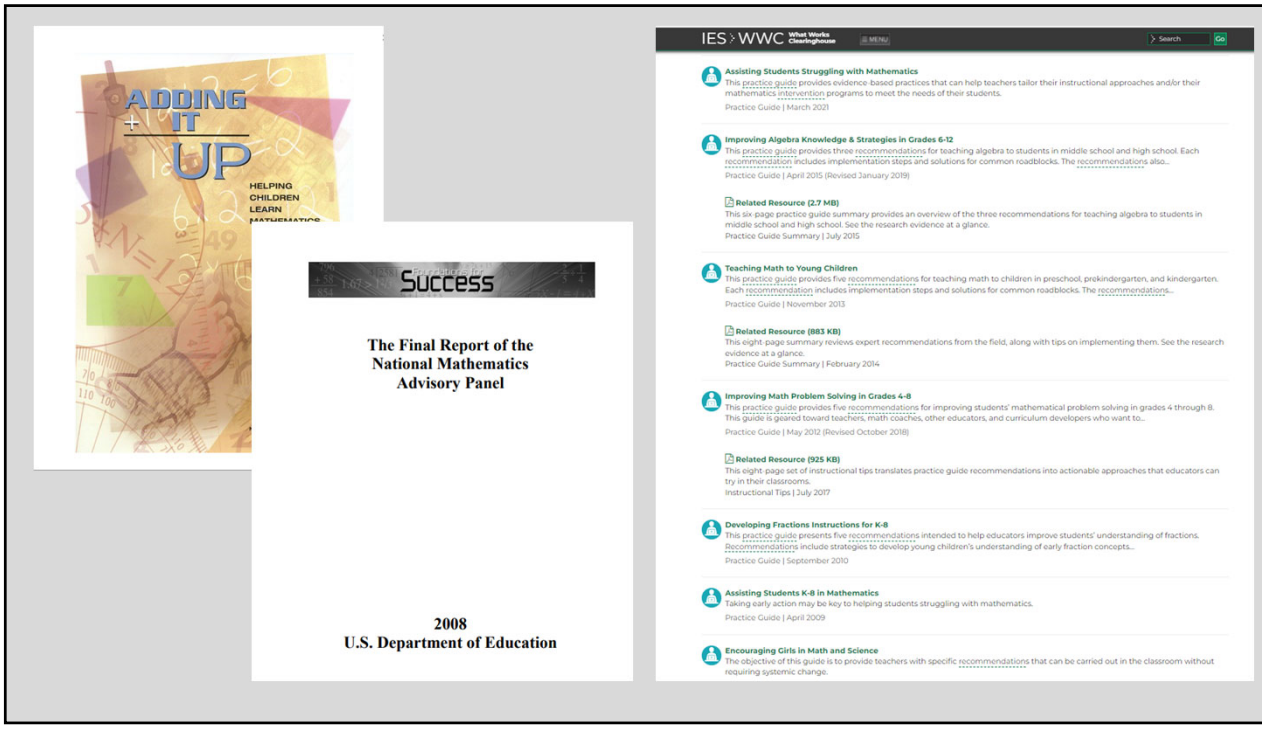
Implementation Challenges

58

Often its Not the Strategy…It's the Application



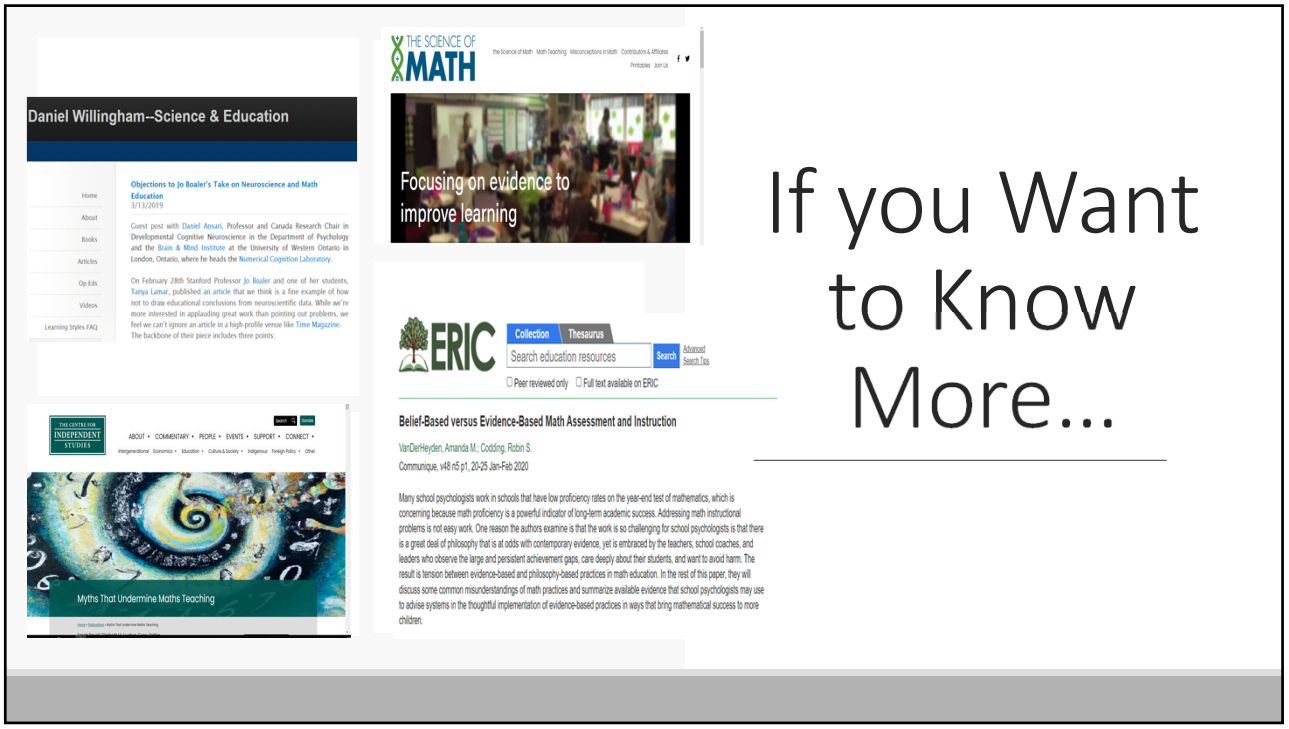
59



60

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

61



62

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

Robin S. Codding, Ph.D.
r.codding@northeastern.edu

63