DOINGWHATWORKS

Improving Mathematical Problem Solving in Grades 4-8

Goal of Doing What Works

Translate research-based practices into examples and practical tools that support and improve classroom instruction.

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Today's Session

- Introduce DWW library as a resource for educators on evidence-based practice.
- Investigate the Mathematical Problem Solving topic.

DOINGWHATWORKS

The U.S. Department of Education has suspended operation of the Doing What Works website. You can still acquire many DWW media and materials through other channels.

- WestEd box for **DWW Materials:**

  https://wested.app.box.com/dww

- Professional Development packages
  - **Research-Based Practices for K-6 Mathematics**
  - **Doing What Works: Adolescent Literacy**
  - **Doing What Works: Improving K-3 Reading Comprehension**
  - **Doing What Works: Increased Learning Time**
  - **Doing What Works: Research-Based Practices for Secondary Schools**
  - **Doing What Works: Using Student Achievement Data to Support Instructional Decision Making**

https://sites.google.com/site/emstlonline/dww

Doing What Works Topics

Literacy

Mathematics and Science

Quality Teaching

Data-Driven Improvement

Comprehensive Support

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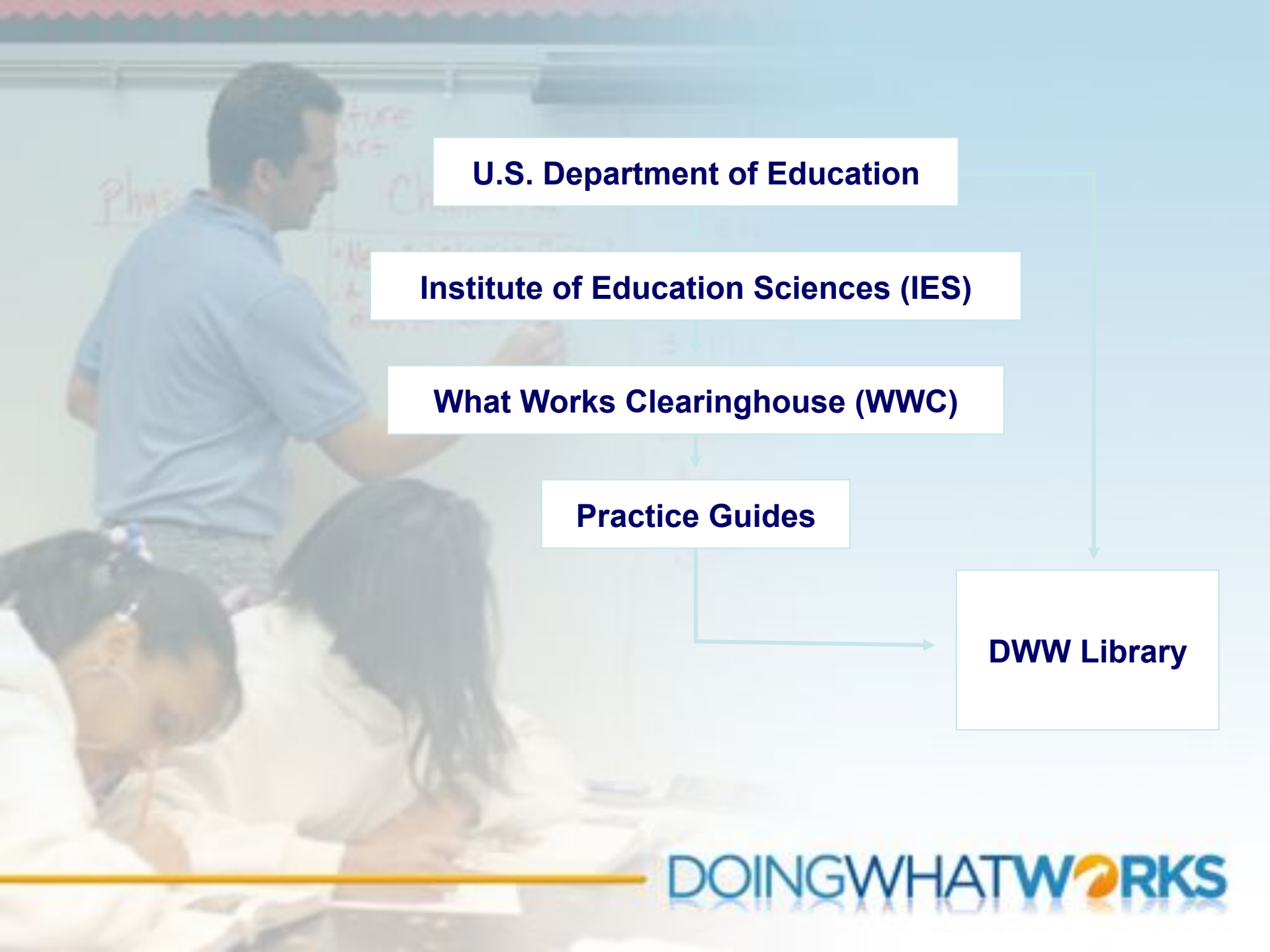
Mathematics Topics

- Encouraging Girls in Math and Science
- National Math Panel:
  - Critical Foundations for Algebra
  - Major Topics of School Algebra
- Developing Effective Fractions Instruction for K-8
- Improving Mathematical Problem Solving in Grades 4 through 8
- Response to Intervention in Elementary-Middle School Mathematics


U.S. Department of Education
Institute of Education Sciences (IES)
What Works Clearinghouse (WWC)
Practice Guides
DWW Library
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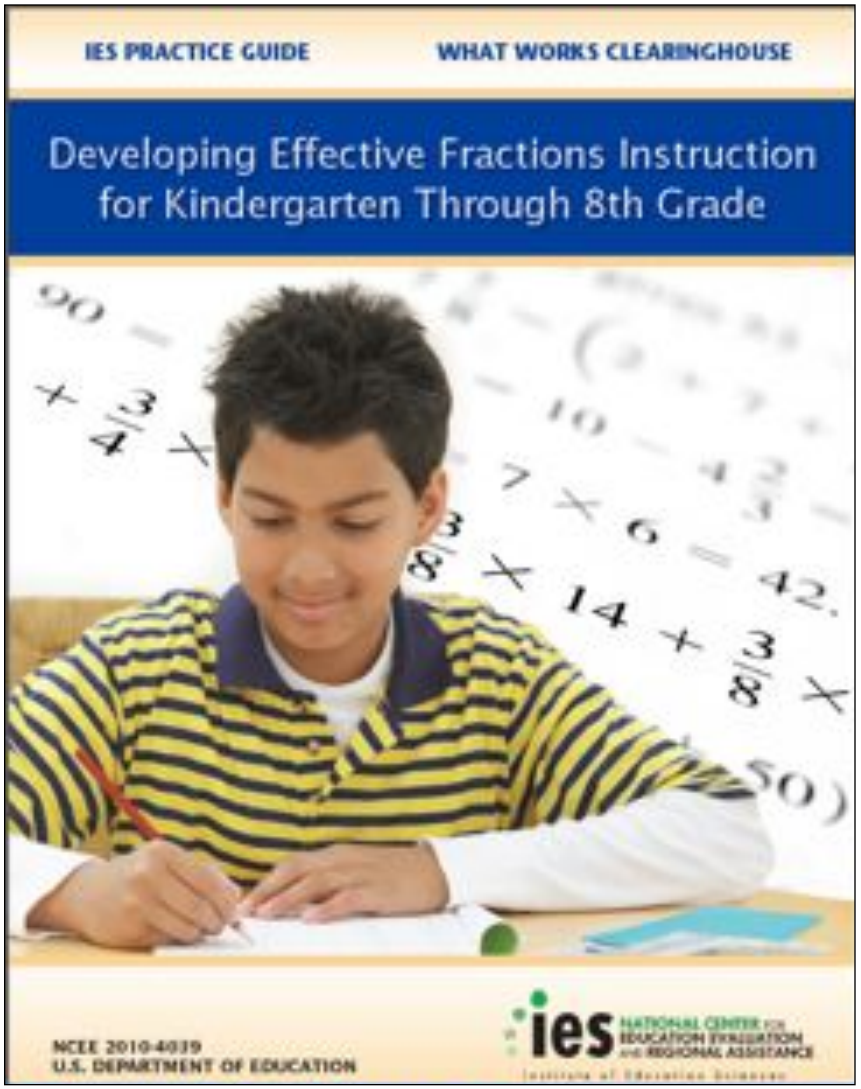
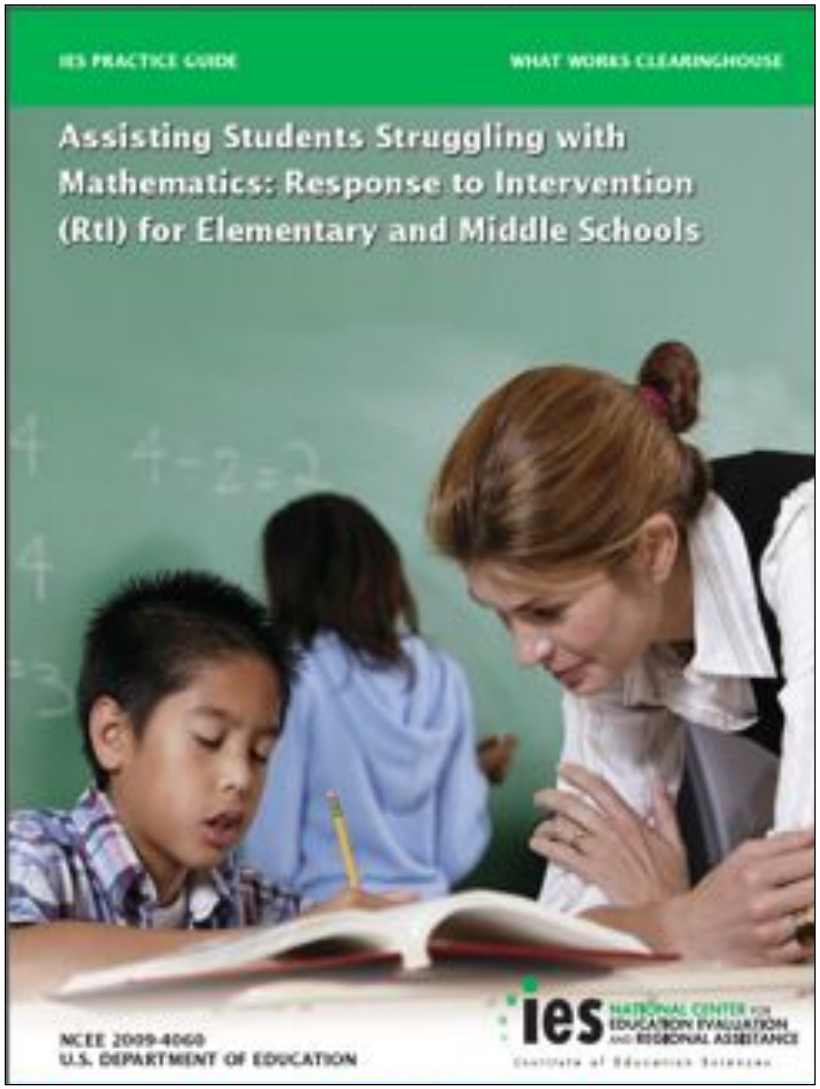
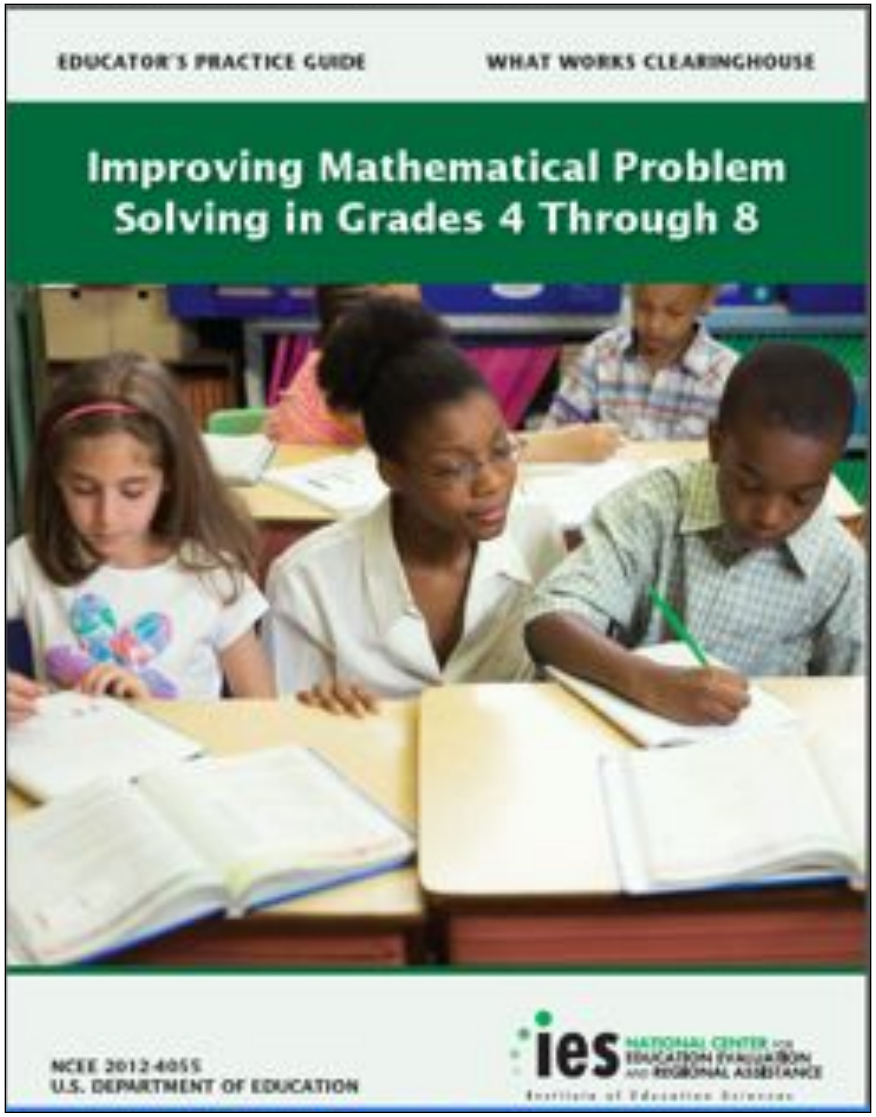
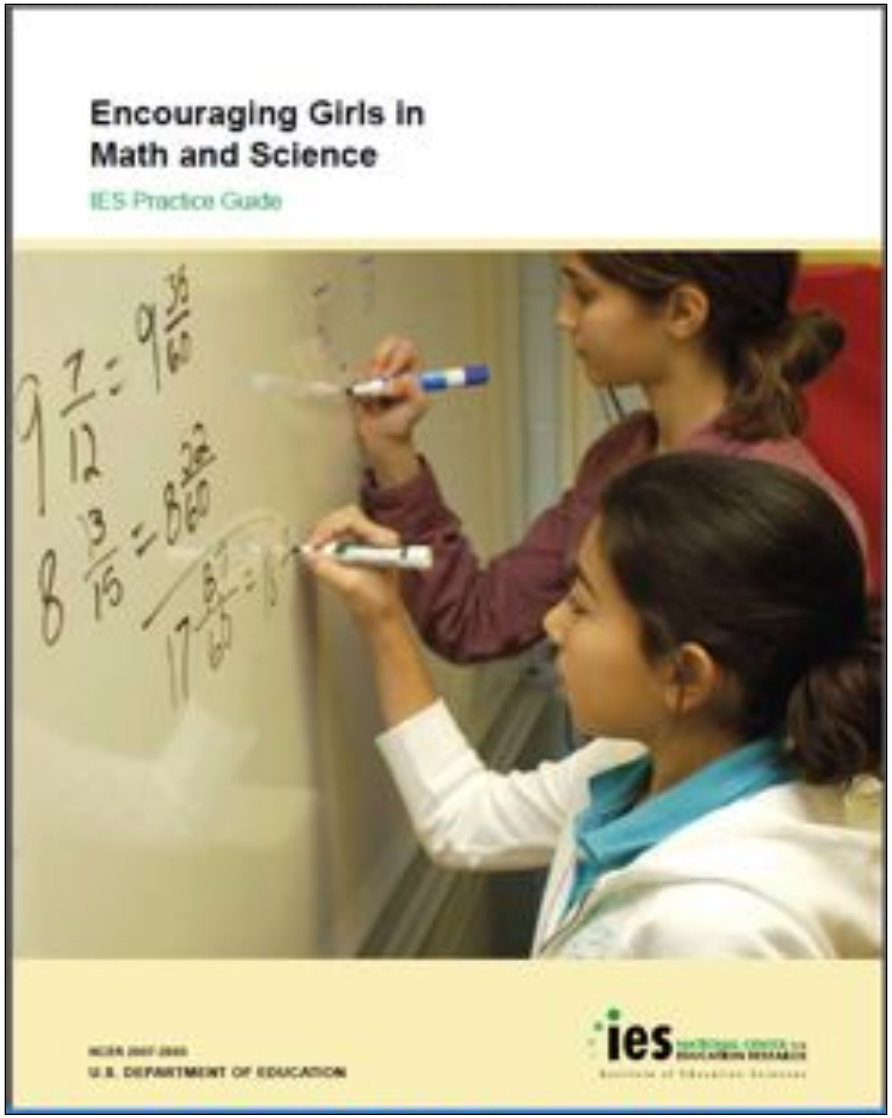
IES What Works Clearinghouse Practice Guides



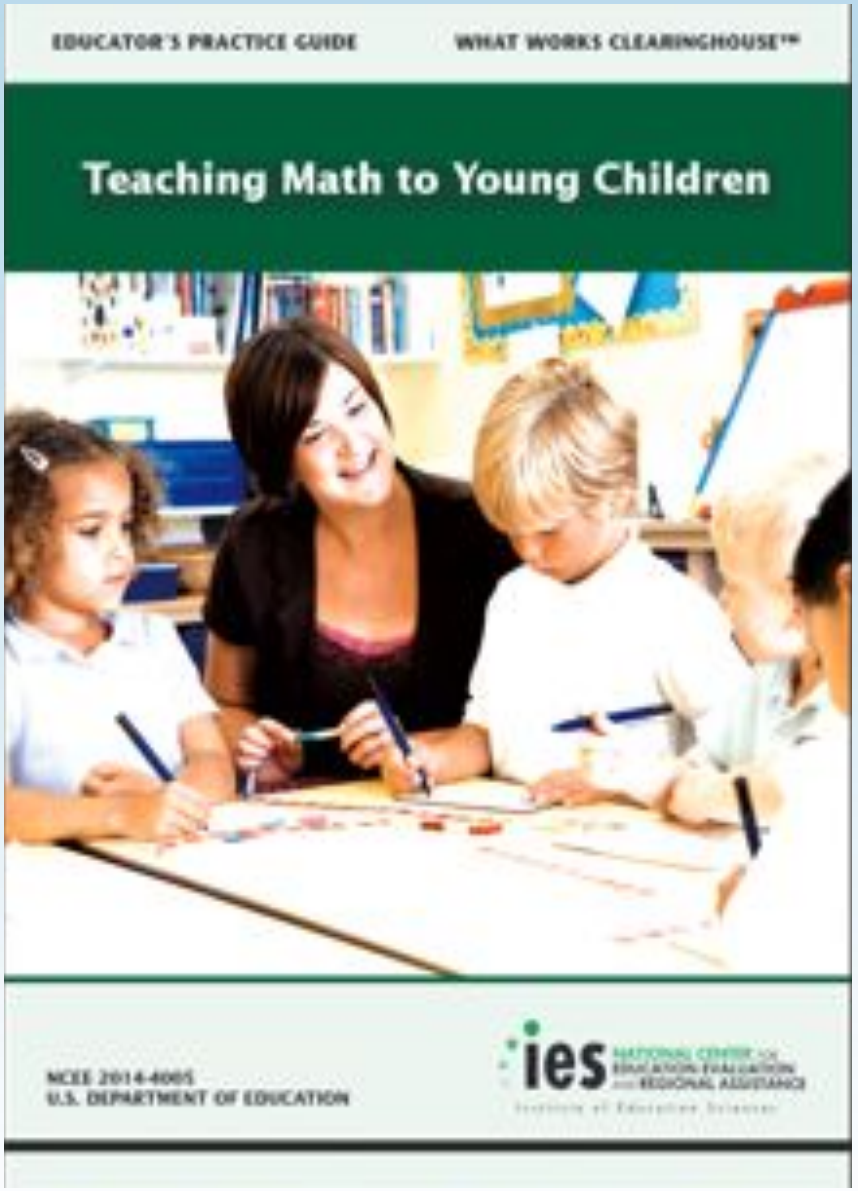


IES What Works Clearinghouse Practice Guides





Newest IES Practice Guide
(November 2013)



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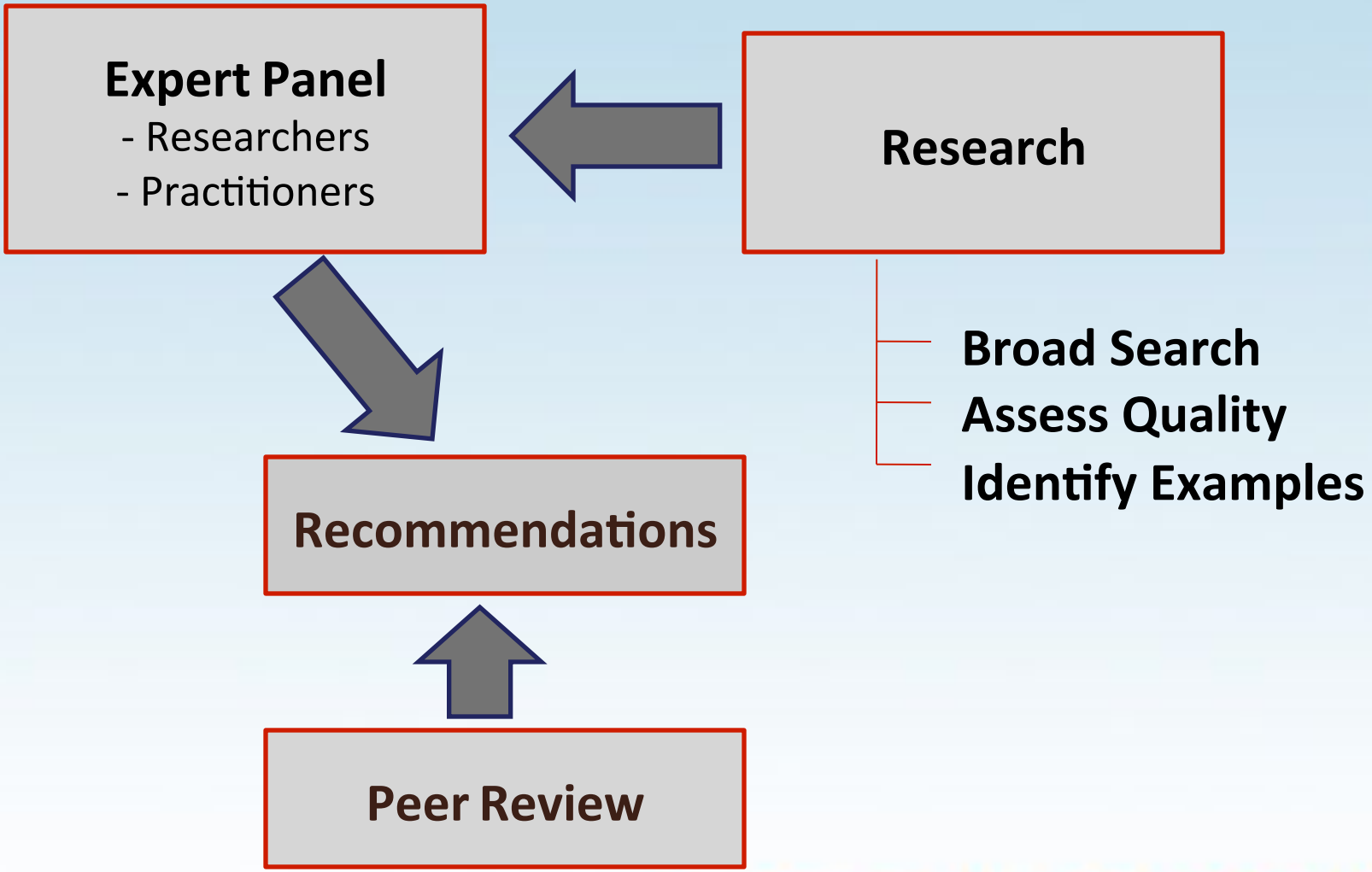
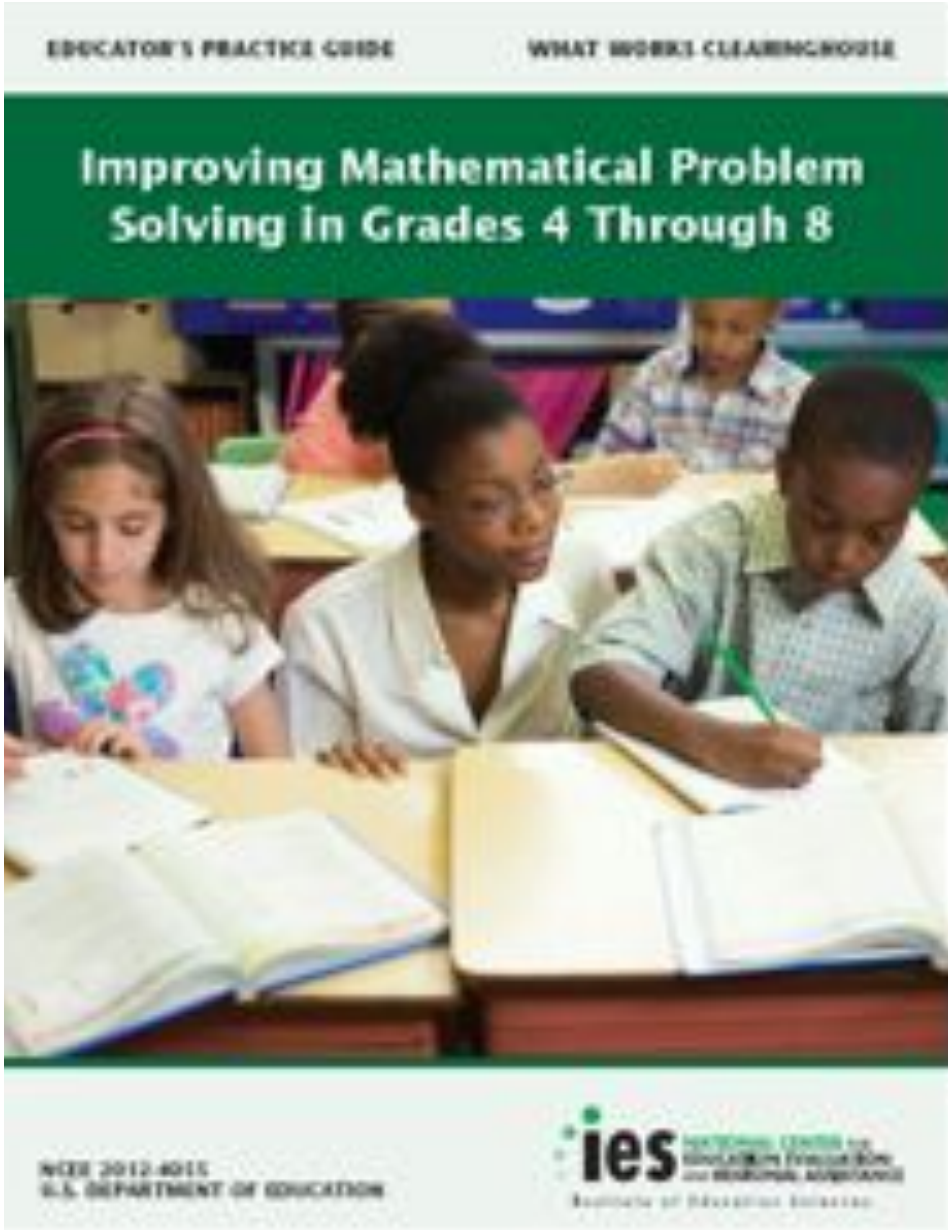
How Practice Guides are Developed





http://ies.ed.gov/ncee/wwc/PracticeGuide.aspx?sid=16

Practice Guide Recommendations

- Prepare problems and use them in whole-class instruction.
- Assist students in monitoring and reflecting on the problem-solving process.
- Teach students how to use visual representations.
- Expose students to multiple problem-solving strategies.
- Help students recognize and articulate mathematical concepts and notations.

Mathematical Practice

1. Make sense of problems and persevere in solving them.
2. Reason abstractly and quantitatively.
3. Construct viable arguments and critique the reasoning of others.
4. Model with mathematics.
5. Use appropriate tools strategically.
6. Attend to precision.
7. Look for and make use of structure.
8. Look for and express regularity in repeated reasoning.

recommendations for improving students' understanding of fractions, rational numbers. Each recommendation includes a summary of the research evidence and a level of evidence rating. This Practice Guide is the foundation for the Doing What Works content on fraction instruction, which merges the five recommendations into four practices.

Access the Practice Guide on the What Works Clearinghouse website.

Overview Media & Materials | State and District Examples | State and District Tools | Related Links

Visual Diagram

Fractions Instruction

This diagram serves as a visual overview of the recommended instructional practices for teaching fractions in elementary and middle school, along with information on the knowledge teachers need to teach fractions effectively. Use this diagram to initiate discussions with teachers about how students' understanding of fractions develops.

DOWNLOAD DIAGRAM | PDF | 87.1 KB

Expert Interview

The Importance of Fractions Instruction

Robert S. Siegler, Ph.D.
Carnegie Mellon University

Dr. Robert Siegler discusses why competence with fractions is critical for more advanced math and why U.S. students have difficulty grasping fractions. He also describes the developmental sequence that grounds learning about fractions in a solid base of conceptual understanding.
(5:36 min)

DOWNLOAD VIDEO | QUICKTIME | 37 MB

TRANSCRIPT & DETAILS | PDF | 169 KB

Expert Interview

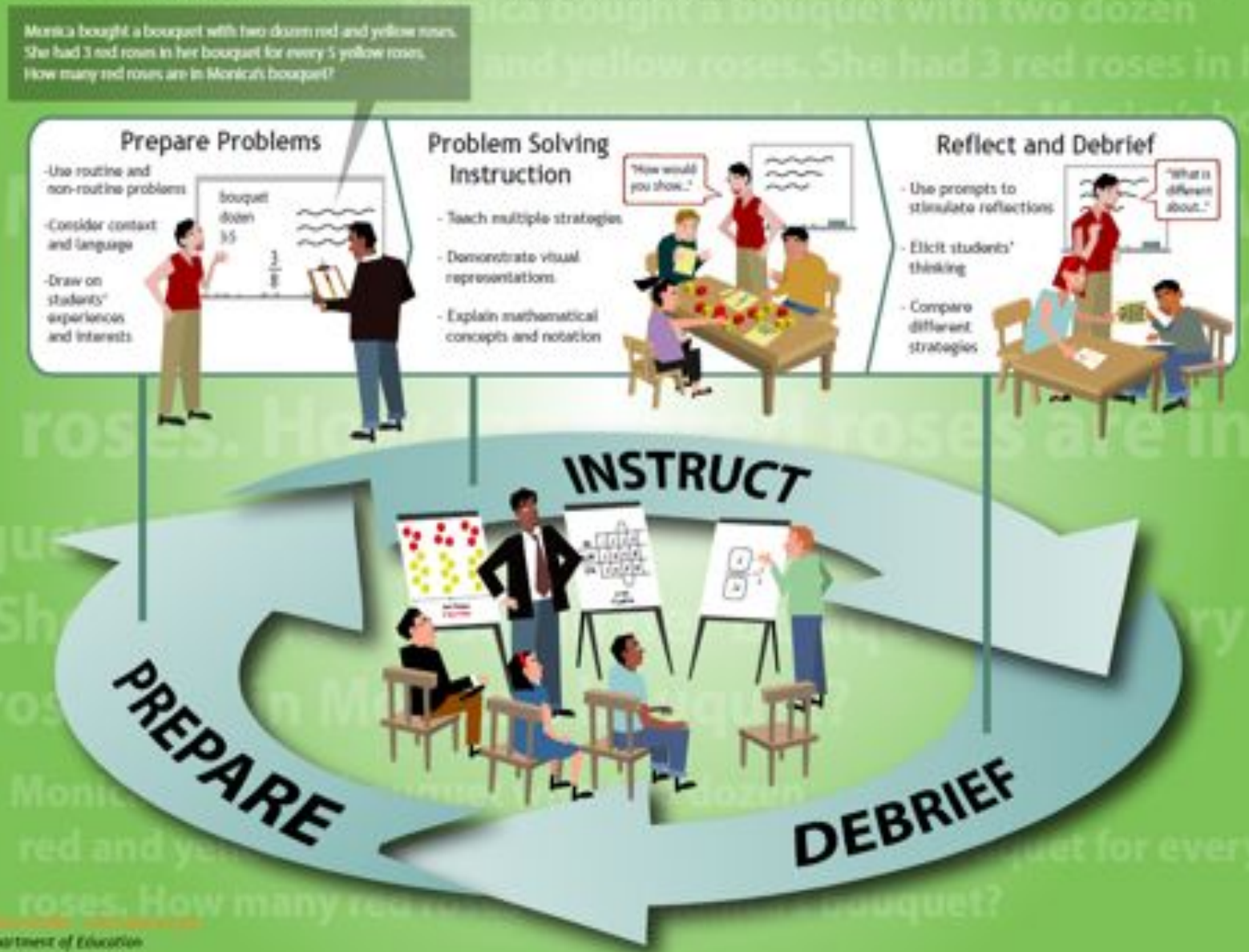
What Teachers Need to Know About Teaching Fractions

Francis (Skip) Fennell, Ph.D.
McDaniel College

Dr. Francis "Skip" Fennell describes the knowledge teachers need to teach fractions effectively, paying special attention to multiple strategies for representing problems involving fractions. He discusses the convergence of curriculum and explores why students and teachers have difficulty with certain fraction

Improving Mathematical Problem Solving in Grades 4 Through 8

The IES Practice Guide *Improving Mathematical Problem Solving in Grades 4 Through 8* details the importance for teachers to incorporate problem solving into classroom instruction. The Guide has recommendations of effective instructional practices for improving students' problem solving skills.



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http://dww.ed.gov

The IES Practice Guide *Improving Mathematical Problem Solving in Grades 4 Through 8* details the importance of teachers incorporating problem solving into their classroom instruction. The Guide has five recommendations of effective instructional practices for improving students' problem solving skills. For purposes of this website, the five recommendations were combined into three practices for conducting a lesson.

This diagram illustrates how five recommendations in the Practice Guide *Improving Mathematical Problem Solving in Grades 4 Through 8* can be implemented in lessons. In the diagram, teachers are shown preparing a problem, providing appropriate problem solving instruction to students, and debriefing the problem solving process with students. It is important for teachers to consider all the practices when conducting a problem-solving lesson. Even though teachers may not use all elements of the practices in every problem-solving lesson, instruction and debriefing of one lesson will support preparation and planning for the next lesson.

Prepare Problems

Problem solving should be an integral part of all mathematics curricular units with time allocated for problem solving in whole-class instruction. Thoughtful preparation of problem-solving activities includes intentionally planning to use a variety of problems, ensuring that students have the language and mathematical experience necessary to solve the problems. Lessons should use routine problems when the goal is for students to understand a mathematical idea and use non-routine problems when the goal is for students to think strategically and apply what they learn.

Monitor and Reflect on the Problem-Solving Process

Monitoring and reflecting during problem solving helps students evaluate the steps they are taking to solve a problem and connect new concepts to what they already know. While the ultimate goal is for students to monitor and reflect on their own while solving a problem, teachers can support students with prompts and can use a thinkaloud to model what they do while solving a problem. Teachers can use student thinking to develop students' ability to monitor and reflect by asking students to explain their reasoning or compare their strategy with other strategies.

Instruction

Visual Representations

Appropriate visual representations (e.g., table, graph, and/or diagram) help students solve problems by linking the relationships between quantities in a problem with the mathematical operations needed to solve the problem. Visual representations help students understand the mathematics involved in a problem and translate information into symbolic notation. Teachers should select and teach visual representations appropriate for students and the problems they are solving.

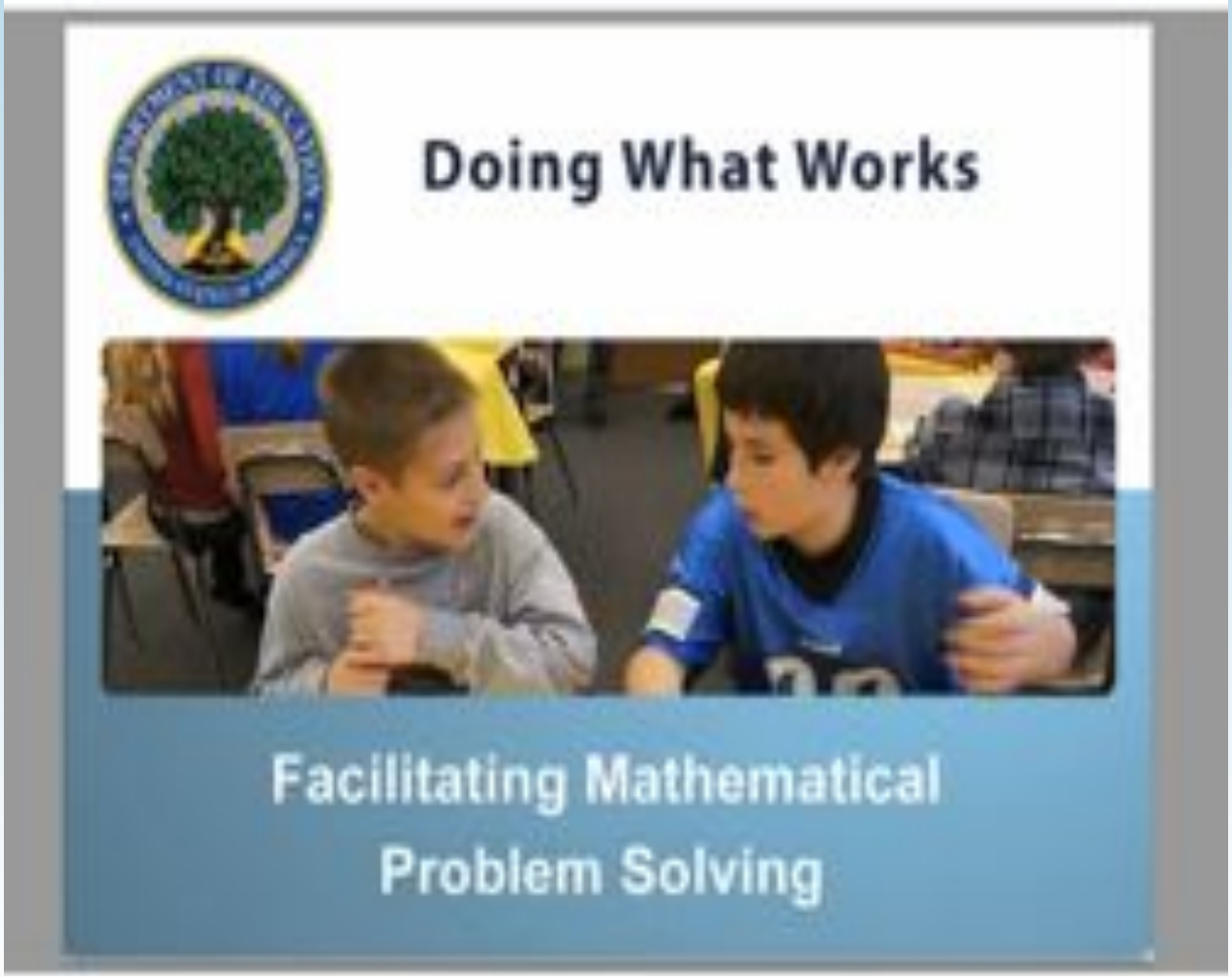
Multiple Problem-Solving Strategies

Successful problem solvers know and use multiple strategies to solve problems. Teachers should encourage students to use strategies that are efficient and make sense to them. Students who practice with multiple problem-solving strategies, sharing and comparing strategies with other students, are able to approach and solve mathematics problems with greater flexibility.

Mathematical Concepts and Notation

Mathematical concepts and notation provide students with structures for organizing information in a problem. Students develop new ways of reasoning when teachers explain relevant concepts and notation in the context of problem solving, prompt students to provide mathematically valid explanations, and help students make sense of algebraic notation.

Topic overview



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Practices

- Prepare Problems
- Problem Solving Instruction
  - Visual Representations
  - Multiple Strategies
  - Concepts and Notation
- Reflect and Debrief

For Each Practice:

- Research base/Instructional presentations
- Expert interviews

- School site videos and slideshows
- Interviews and sample materials from schools

- Ideas for action
- Tools and templates to implement practices

	LEARN	SEE	DO
Prepare Problems	Overview Experts: Philip Ogbuehi, Patricia Herzig	Coach Talk: Preparing for Problem Solving Lesson Pre-Conference & Sample Materials	--Workshop: Learning Together about Preparing Problems --Self Assessment: Checklist for Problem Planning --Planning worksheet: Planning and Adapting Problems
Problem-Solving Instruction (visual representations, multiple strategies, concepts and notation)	Overview Experts: Asha Jitendra Mark Driscoll Ken Koedinger	Nine Classroom Videos & Sample Materials	--Walkthroughs: Teaching Problem Solving --Workshop: Using Visuals --Reference: Connecting visuals to problem types --Observation: Multiple Approaches to Problem Solving
Reflect and Debrief	Overview Experts: Sybilla Beckmann Mark Driscoll	Three Classroom Videos & Sample Materials	--Workshop: Learning together about Monitoring and Debriefing --Observation: Students' Understanding of Process --Planner: Developing Thinkalouds -- Debriefing Student Solutions

Prepare Problems

LEARN: Research Findings

- **Improved performance on word problems when context is familiar and of interest**
- **Improved performance when teacher planning of problems takes student language and math content understanding into account**

Implications for Instruction

- **Frequent opportunities for whole class problem solving**
- **Advance preparation to adapt problems for students**
- **Use routine/non-routine problems**

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DWW Tool

Planning tool to guide review and adaptation of problems

Instructional Strategies

Teach students to use visual representations, employ multiple problem-solving strategies, and relate mathematical concepts and notation to problem solving.

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LEARN: Research Findings

- **Students who visually represent mathematical information prior to writing an equation are more effective at problem solving.**
- **Using visual representations is most effective when students design their own representations**
- **More successful problem solvers are more efficient in selecting approaches to problems because they know how to use multiple strategies.**
- **Using worked examples and asking students to explain the process improves problem solving.**

Teach students to use visual representations, employ multiple problem-solving strategies, and relate mathematical concepts and notation to problem solving.

Multiple Problem-Solving Strategies in Instruction

Mark J. Driscoll, Ph.D., September 2011

[redacted]

Description

Dr. Driscoll explains how use of multiple strategies contributes to student learning by letting students see problems in new ways. He stresses the importance of worked examples and comparing and contrasting strategies (5:37 min). Click here for transcript.

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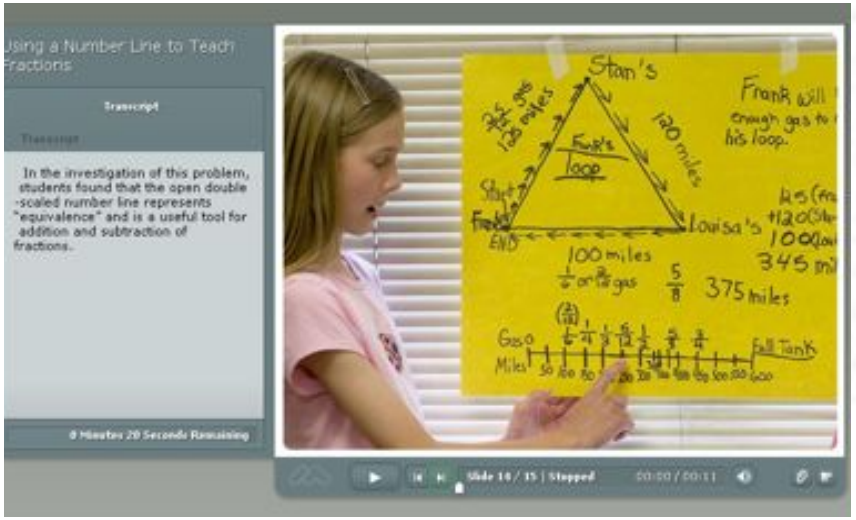
See How: Visualizations

Frank runs a business called Frank's Fresh Farm Produce. Once a week he drives north of the city to farms where he buys the best possible fresh produce for his customers. Frank can travel 600 miles on a full tank of gas. His truck has a fancy, accurate fuel gauge.

Usually Frank has time to visit only one farm on each trip, but this week he decides to visit both Stan's and Louisa's farms. When Frank drives from his store to Stan's farm and back, he knows he uses 5/12 of a tank of gas. When he drives to Louisa's farm and back, he uses 1/3 of a tank. From a map of the area, he learns that there is a road from Stan's farm to Louisa's farm that is 120 miles long. He realizes that he can drive from his store to Stan's farm, then to Louisa's farm, and then back to his store in one loop.

Frank can tell by looking at the fuel gauge that he has 5/8 of a tank of gas. Can he drive this loop without having to stop for fuel? Or should he buy gas before he starts his trip?



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SAMPLE MATERIAL

Frank's Problem

Madison Elementary School, Washington

Topic: Improving Mathematical Problem Solving in Grades 4 Through 8

Practice: Problem-Solving Instruction

Madison Elementary School sixth graders work in groups and use visual representations to present their solutions to this math problem about Frank's Fresh Farm Produce. In addition to the problem statement, this

Frank runs a business called Frank's Fresh Farm Produce. Once a week he drives north of the city to farms where he buys the best possible fresh produce for his customers. Frank can travel 600 miles on a full tank of gas. His truck has a fancy, accurate fuel gauge.

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ank's Fresh Farm Produce—Madison Elementary School, Washington

DOINGWHATWORKS

Connecting Visuals to Problem Types

When planning instruction on using visual representations in problem solving, math coaches and teachers can refer to this summary of information from the *Improving Mathematical Problem Solving in Grades 4 Through 8* Practice Guide. For each type of visual representation, the chart below includes the kinds of problems it can be used to solve, with several problem examples.

As a precursor to using this tool, teachers may want to watch the video interview with Dr. Asha Jitendra, *Matching Visuals to Purpose in Problem Solving*, where she talks about the role of different types of visual representations and suggests a problem where more than one visual representation could be used. Additional examples can be viewed in the *Effective Problem-Solving Instruction* overview and in the classroom presentations of *Multiplication of Fractions Problem* and *Problem Solving in Pre-Algebra*. Note that some problems can be appropriately represented by several types of visual representations.

Visual Representations for Different Problem Types

Visual Representation	Problem Types	Relevant Examples of Problems
Tables (including function tables and ratio tables)	Patterns and establishing rules Functional relationships Ratios and proportions Multiplication and division	On the playground there are some tricycles and some wagons. There are five more tricycles than wagons. When you count the wheels on all the vehicles, there are exactly 36 wheels. How many tricycles and how many wagons are on the playground? In Ms. Jacobs' class there are 3 girls for every 4 boys (the ratio of girls to boys is 3:4). There are 28 students in the class. How many boys and how many girls are in the class? Paul says he uses 1 ½ liters of paint to paint a fence 8 meters long. He would like to know how much paint to buy if the fence he needs to paint is 20 meters long. Alice's walking rate is 2.5 meters per second. Her younger brother, Mark, walks 1 meter per second. Because Alice's rate is faster than Mark's, Alice gives Mark a 45-meter head start in a 100-meter walking race. What happens in the race?
Number Lines (including open number lines and double number lines)	Addition and subtraction problems Proportions Various types of percent problems	In Ms. Jacobs' class there are 3 girls for every 4 boys (the ratio of girls to boys is 3:4). There are 28 students in the class. How many boys and how many girls are in the class? Paul says he uses 1 ½ liters of paint to paint a fence 8 meters long. He would like to know how much paint to buy if the fence he needs to paint is 20 meters long. Ms. Thompson has 40 show dogs and 14 are Labradors.
Strip Diagrams (or Bar Diagrams)	Combination with parts unknown Fraction change with start unknown Comparison Ratio and proportion	A family of three adults and three children goes to an amusement park. Adult admission fare is twice as much as a child's. The family spends $81. How much is the adult admission fare? How much is the child admission fare? Eva spent 2/5 of the money she had on a coat, and then she spent 1/3 of what was left on a sweater. She had $70 remaining. How much did she start with? Pies are very popular at the fair, so the baker made lots of pies early in the morning. He sold 2/5 of the pies before noon. Then he sold 1/2 of the remaining pies in the afternoon. 12 more pies were sold in the morning than in the afternoon. How many pies did the baker make? Carla and Jessica each have some money. Carla has $11 more than Jessica. How much does Carla have? How much does Jessica have?
Percent Bars	Various types of percent problems	During a sale, prices were marked down by 20%. The sale price of an item was $84. What was the original price of the item before the discount?
Grids or Arrays (including area maps and coordinate graphs)	Fraction problems Functional relations	There was a candy bowl on the table. Amanda had a sweet tooth, so she ate half of the candies in the bowl. Ed came along and thought the candy looked good, so he ate a third of what was left. Heather came by and took a fourth of the remaining candies for a snack. Jerome came rushing by and took just one piece of candy. When Kristi looked into the candy bowl, she noticed there were two pieces of candy left. "How many candies were in the bowl to begin with?" Kristi asked. Mrs. Logan went to the Pride Council bake sale to buy some brownies. All pans of brownies cost $12. Customers can buy any fractional part of a pan and pay that fraction of $12. Mrs. Logan bought 3/4 of a pan that was 2/5 full. How much did she pay? Alice's walking rate is 2.5 meters per second. Her younger brother, Mark, walks 1 meter per second. Because Alice's rate is faster than Mark's, Alice gives Mark a 45-meter head start in a 100-meter walking race. What happens in the race?
Schematic Diagrams	Multiple-step problems Ratio and proportion problems Various percent problems	John recently participated in a 5-mile run. He usually runs 2 miles in 30 minutes. Because it was a particularly warm day, he decided to take a 5-minute break after every mile to drink 4 ounces of water. How much time did it take him to complete the 5-mile run? During a sale, prices were marked down by 20%. The sale price of an item was $84. What was the original price of the item before the discount?

Using Visual Representations

Problem 1.

On the playground there are some tricycles and some wagons.
There are five more tricycles than wagons.
When you count the wheels on all the vehicles, there are exactly 36 wheels.
How many tricycles and how many wagons are on the playground?

Table

# of tricycles	# of wagons	wheels on tricycles	Wheels on wagons	Total wheels
5	0	15	0	15
6	1	18	4	22
7	2	21	8	29
8	3	24	12	36

The table starts at 5 tricycles and 0 wagons because there are 5 more tricycles than wagons.

Pictorial

3 x 8 = 24

4 x 3 = 12

Total 36

Equations

Let t be the number of tricycles and w be the number of wagons. Then,

$$t = w + 5$$

$$3t + 4w = 36$$

Reflect and Debrief

Research Findings

- Students solve problems better when they monitor their thinking and problem-solving steps.
- The more students reflect on their problem-solving processes, the better their mathematical reasoning.

Implications for Instruction

- Provide prompts.
- Model how to monitor and reflect.
- Use student thinking to develop students' ability to monitor.

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Monitoring the Problem-Solving Process

Sybilla Beckmann, Ph.D., September 2011

Audience: Specialists/coaches, administrators, teacher leaders, teachers

Suggested Use: Professional development, formative assessment

Doing What Works

Monitoring Progress While Solving Problems

Reflect and Debrief

Practice Summary | Learn What Works | See How It Works | Do What Works

Solving a Real-World Fraction Division Problem

(5:41 min)

- DOWNLOAD VIDEO | QUICKTIME | 60 MB
- TRANSCRIPT & DETAILS | PDF | 952 KB

Presentations

Monitoring Progress While Solving Problems

Solving a Real-World Fraction Division Problem
A 5th-grade teacher poses a fraction division problem and challenges students to find different approaches to a solution.

Coach Talk: Debriefing in Problem Solving

Back to top

Solving a Real-World Fraction Division Problem

Eliza Hart Spalding School of Math and Technology (ID)

A fifth-grade teacher poses a fraction division problem and challenges students to find different approaches to a solution. One student uses a number line; others use build-up strategies. See their assignment in *Web Shots for Spiderman Problem*. **(6:41 min)**

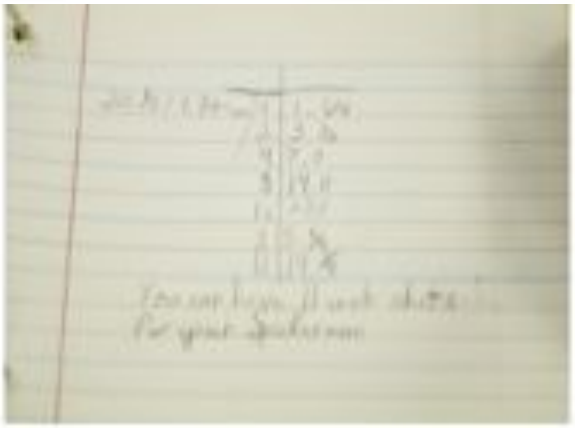
- DOWNLOAD VIDEO | QUICKTIME | 60 MB
- TRANSCRIPT & DETAILS | PDF | 960 KB

Web Shots for Spiderman

Zayd and I were playing in the garage and he wanted to be just like Spiderman. He asked if we could make him a web shooter out of rope that he found.

To make each web shot, it takes 1 ¾ inch of rope. If he found 20 ½ inches of rope, how many web shots can we make for my Spiderman?

What is the mathematical sentence? Then solve.



Reflect and Debrief

Ideas for Action | Tools & Templates

Monitor and reflect on the problem-solving process, and debrief to explain and compare problem-solving strategies.

Practice Tools

These tools and templates help you use the materials in the "Learn What" and "See How" sections as you tackle the hard work of school improvement. Each tool is a downloadable Word document that you can edit and adapt to serve your needs.

Learning Together About Monitoring and Debriefing

With this workshop, professional development providers can help teachers practice facilitating their students' monitoring of their thinking during problem solving and verbalizing alternative ways to proceed at each step of the process.

DOWNLOAD TOOL | WORD | 226 KB

Observing Students' Understanding of the Problem-Solving Process

Teachers can use this observation tool to monitor students' understanding of the problem-solving process and determine needs for additional instruction.

DOWNLOAD TOOL | WORD | 272 KB

Developing Problem-Solving Thinkalouds

This instructional planner helps mathematics coaches and teachers plan how they will demonstrate to students how to reflect on their thinking as they solve problems. The planner helps prepare a thinkaloud.

DOWNLOAD TOOL | WORD | 235 KB

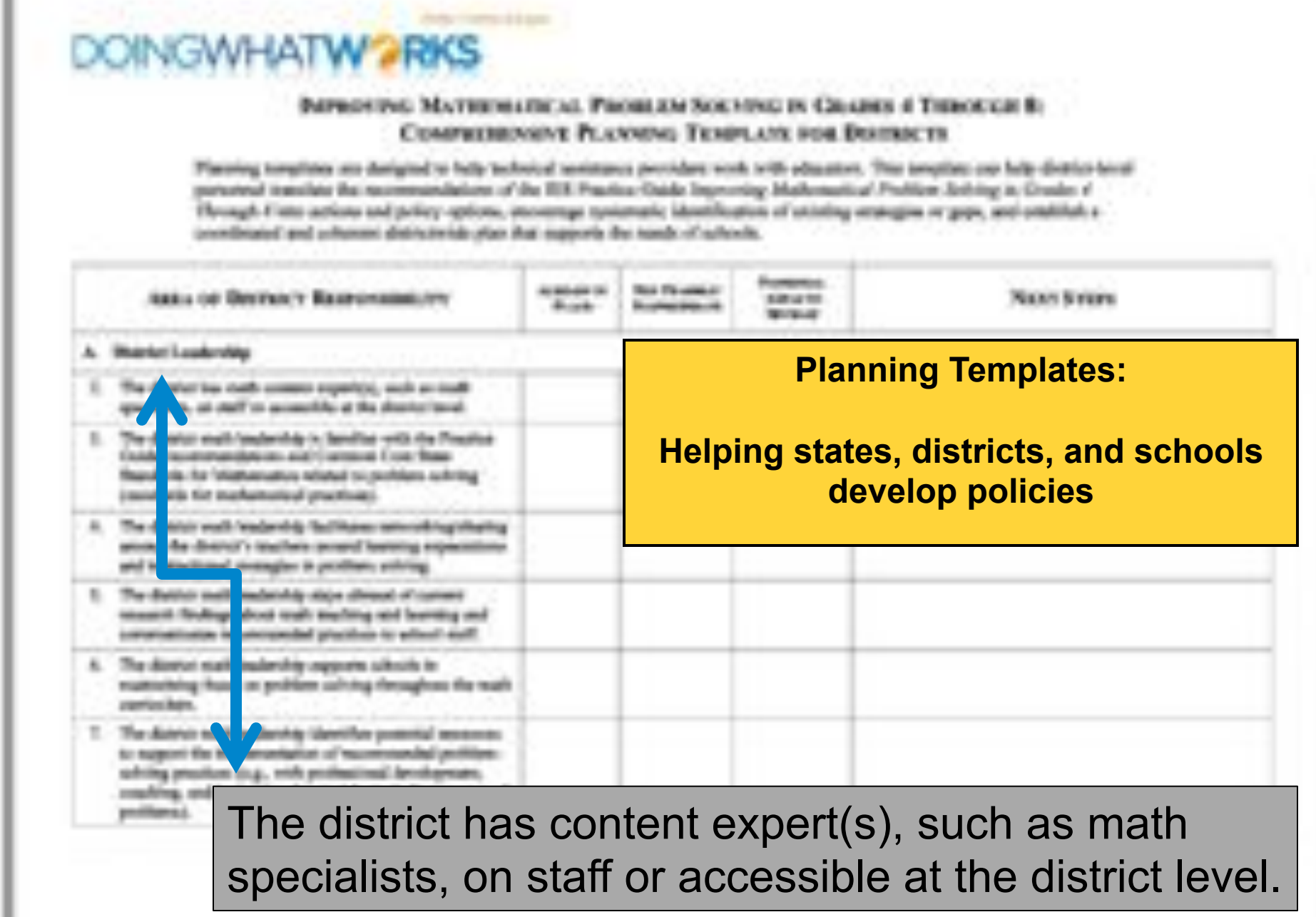
Debriefing Student Solutions

Teachers can use this tool as a guide to help them remember prompts and strategies that extend students' thinking about problem solving while they debrief different approaches to solving a problem.

DOWNLOAD TOOL | WORD | 160 KB

Common Core State Standards for Mathematics Standards for Mathematical Practices Emphasis on Problem Solving	Current Status in District/State Standards	Current Status in Present Instructional Materials
1. Make sense of problems and persevere in solving them.		
Mathematically proficient students start by explaining to themselves the meaning of a problem and looking for entry points to its solution. They analyze givens, constraints, relationships, and goals. They make conjectures about the form and meaning of the solution and plan a solution pathway rather than simply jumping into a solution attempt. They consider analogous problems, and try special cases and simpler forms of the original problem in order to gain insight into its solution. They monitor and evaluate their progress and change course if necessary. Older students might, depending on the context of the problem, transform algebraic expressions or change the viewing window on their graphing calculator to get the information they need. Mathematically proficient students can explain correspondences between equations, verbal descriptions, tables, and graphs or draw diagrams of important features and relationships, graph data, and search for regularity or trends. Younger students might rely on using concrete objects or pictures to help conceptualize and solve a problem. Mathematically proficient students check their answers to problems using a different method, and they continually ask themselves, "Does this make sense?" They can understand the approaches of others to solving complex problems and identify correspondences between different approaches. • *The Components of Problem Solving*—**Expert Interview** [Improving Mathematical Problem Solving in Grades 4-8 Topic: Overview: Media and Materials] • *Preparing Problems for Class Instruction*—**Multimedia Overview** [Prepare Problems: Practice Summary] • *Designing Worthwhile Problems*—**Expert Interview** [Prepare Problems: Practice Summary] • *Coach Talk: Preparing for Problem Solving*—**Interview** [Prepare Problems: See How it Works] • *Representing a Problem Visually*—**Classroom Lesson** [Problem-Solving Instruction: See How it Works] • *Monitoring the Problem-Solving Process*—**Expert Interview** [Reflect and Debrief: Practice Summary]		

Comprehensive Tools and Templates


DOINGWHATWORKS
Planning Templates:
Helping states, districts, and schools develop policies
The district has content expert(s), such as math specialists, on staff or accessible at the district level.

DWW Resource Inventories

Topic: Improving Mathematical Problem Solving in Grades 4 Through 8 (PS)

Topic inventories list every component of a DWW topic. Use this document to get an overview of the *Improving Mathematical Problem Solving in Grades 4 Through 8* topic, identify multimedia pieces, and plan for professional development.

Practice Guide

Resource	Description
Improving Mathematical Problem Solving in Grades 4 Through 8	This practice guide provides five recommendations for improving students' mathematical problem solving in grades 4 through 8: • Prepare problems and use them in whole-class instruction. • Assist students in monitoring and reflecting on the problem-solving process. • Teach students how to use visual representations. • Expose students to multiple problem-solving strategies. • Help students recognize and articulate mathematical concepts and notation.

Topic Summary

Resource	Featured Expert	Description
Improving Mathematical Problem Solving in Grades 4 Through 8 (presentation, 5:45 min)	N/A	• This multimedia overview explains why problem solving should be part of teaching in all math topics. • Problem-solving skills are essential for students as they progress through the entire mathematics curriculum – from early informal understanding through advanced mathematics. Students who learn early to analyze problems, follow a reasoning process, and construct

1. Overview Multimedia & Materials

Resource	Featured Expert	Description
Improving Mathematical Problem Solving in Grades 4 Through 8 Visual Diagram (.pdf)	N/A	The visual diagram illustrates three essential practices (preparation of problems, instructional approaches, and reflection and monitoring) based on the recommendations in the Practice Guide. Use this diagram to get a big picture understanding of the processes involved in problem solving.
The Components of Problem Solving (video, 5:45 min)	John P. Woodward, Ph.D. University of Puget Sound	Dr. John Woodward describes the IES Panel's five recommendations related to the problem-solving process and shows different types of problems. • Problem solving goes beyond word problems, and includes symbol manipulation and visual analysis. • In countries that do well on math assessments, a significant portion of instruction involves math problem solving.

DWW Materials: https://wested.app.box.com/dww

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