Participant Handout

Strategies to Enhance Long-Term Learning

Retrieval Practice

For problems 1–12, solve the equation.

1. $x + 6 = 10$
2. $x - 2 = 9$
3. $2x = 6$
4. $3x + 5 = 17$
5. $4(x + 1) = 8$
6. $3x + 6 - x = 14$
7. $4x + 10 = x + 1$
8. $3(2x - 1) = 6x - 7$
9. $x^2 - 9 = 0$
10. $x^2 + 2x - 48 = 0$
11. $3x^2 + 4x + 1 = 0$
12. $x^4 - 5x^2 + 4 = 0$

Retrieval Practice

> "Retrieval practice is a learning strategy where we focus on getting information out. Through the act of retrieval, or calling information to mind, our memory for that information is strengthened and forgetting is less likely to occur."[1]

Retrieval Practice Reading

1. Read the excerpt from *How to Use Retrieval Practice to Improve Learning*.

2. Consider using the following symbols to react to the reading.

   ! surprise

   ☺ agreement or affirmation

   ? need for clarification

   # disagreement

3. Briefly share your reactions to the reading with a partner.

DOES RETRIEVAL IMPROVE MORE THAN JUST MEMORIZATION?

By using retrieval practice as a learning strategy (not an assessment tool!), we exercise and strengthen our memory. Research demonstrates that this improvement in memory and long-term learning is **flexible**, which:

- Improves students' complex thinking and application skills
- Improves students' organization of knowledge
- Improves students' transfer of knowledge to new concepts

In other words, retrieval practice doesn't just lead to memorization – it increases **understanding**. Because students have a better understanding of classroom material by having practiced using this information, students can adapt their knowledge to new situations, novel questions, and related contexts. You can use a variety of question types (fact-based, conceptual, complex or higher order, etc.) to ensure that students are not memorizing, but using information flexibly.

As an additional benefit, retrieval practice helps us to identify gaps in learning. In other words, not only does retrieval improve learning and help us figure out what we do know – more importantly, it helps us figure out what we don't know. This crucial benefit of retrieval practice is called **metacognition**, or awareness of what students know and don't know. For instance, some students study hard for tests and don't do well, usually because they studied what they already knew – they didn't study what they didn't know. By engaging in retrieval practice, students are able to evaluate what they know and what they don't know, and then make better study decisions. Improved metacognition also benefits teachers: by seeing what students know and don't know, teachers can

[1] Pooja K. Agarwal, How to Use Retrieval Practice, p. 2

adjust lesson plans to ensure that all students are on the same page (similar to formative assessment). An important component of metacognition is **feedback**, or providing students information about whether they got something correct or incorrect. Without feedback, students won't know how they performed. Thus, feedback should **always** be provided to students after retrieval practice.[2]

Reflecting on Retrieval Practice

1. What retrieval practice is going well in your classroom? How do you know?

2. How can you improve existing retrieval practice in your classroom?

[2] Pooja K. Agarwal, How to Use Retrieval Practice, p. 2.

Spaced Practice

> "Spaced practice involves taking a given amount of time devoted to learning, and arranging that time into multiple sessions that are spread over time. In this way, the learning sessions are said to be 'spaced' apart in time."[3]

Consider the daily, weekly, monthly, and yearly practice opportunities students have in your classroom.

1. List spaced practice opportunities already occurring in your classroom.

2. Are the spaced practice opportunities already occurring in your classroom used as assessment tools or learning strategies?

[3] Pooja K. Agarwal, *How to Use Spaced Retrieval*, p. 3.

Retrieval Practice Plan

The X's represent opportunities to practice operating with numbers written in scientific notation.

Grade 8 Module 1		
Lesson Title	**Embedded in Lesson**	**Retrieval Practice**
Lesson 1: Large and Small Positive Numbers		
Lesson 2: Comparing Large Numbers	X	
Lesson 3: Time to Be More Precise – Scientific Notation		
Lesson 4: Adding and Subtracting Numbers Written in Scientific Notation	X	
Lesson 5: Products of Exponential Expressions with Whole Number Exponents	X	
Lesson 6: More Properties of Exponents		
Lesson 7: Making Sense of the Exponent of 0	X	
Lesson 8: Making Sense of Integer Exponents		X
Lesson 9: Writing Equivalent Expressions		
Lesson 10: Evaluating Numerical Expressions by Using Properties of Exponents		
Lesson 11: Small Positive Numbers in Scientific Notation	X	
Lesson 12: Operations with Numbers in Scientific Notation	X	
Lesson 13: Applications with Numbers in Scientific Notation	X	
Lesson 14: Choosing Units of Measurement	X	
Lesson 15: Get to the Point	X	

Lesson 16: Perfect Squares and Perfect Cubes		
Lesson 17: Solving Equations with Squares and Cubes		X
Lesson 18: The Pythagorean Theorem		
Lesson 19: Using the Pythagorean Theorem		
Lesson 20: Square Roots		X
Lesson 21: Approximating Values of Roots and π^2		
Lesson 22: Familiar and Not So Familiar Numbers		X
Lesson 23: Ordering Irrational Numbers		
Lesson 24: Revisiting Equations with Squares and Cubes		
Mixed Practice		

Grade 8 Module 2		
Lesson Title	**Embedded in Lesson**	**Retrieval Practice**
Lesson 1: Motions of the Plane		X
Lesson 2: Translations		
Lesson 3: Reflections		
Lesson 4: Translations and Reflections on the Coordinate Plane		
Lesson 5: Rotations		
Lesson 6: Rotations on the Coordinate Plane		
Lesson 7: Working Backward		
Lesson 8: Sequencing the Rigid Motions		
Lesson 9: Ordering Sequences of Rigid Motions		
Lesson 10: Congruent Figures		
Lesson 11: Showing Figures Are Congruent		
Lesson 12: Lines Cut by a Transversal		X
Lesson 13: Angle Sum of a Triangle		
Lesson 14: Showing Lines Are Parallel		
Lesson 15: Exterior Angles of Triangles		
Lesson 16: Find Unknown Angle Measures		
Lesson 17: Proving the Pythagorean Theorem		

Lesson 18: Proving the Converse of the Pythagorean Theorem		
Lesson 19: Using the Pythagorean Theorem and Its Converse		
Lesson 20: Distance in the Coordinate Plane		
Lesson 21: Applying the Pythagorean Theorem		
Lesson 22: On the Right Path		
Mixed Practice		X

What do you notice?

What do you wonder?

Spaced Practice Reading

1. Form a triad.

2. Each member of the triad selects and silently reads a different frequently asked question and response from *How to Use Spaced Retrieval Practice to Boost Learning*.

3. When all members of the triad have finished reading, take turns sharing the answer to the question in your own words.

FREQUENTLY ASKED QUESTIONS

How much spacing is enough?

In general, the more, the better. Spaced practice is beneficial whether the lessons occur on consecutive days, one week apart, or even several weeks apart. Research shows that any spacing is better than no spacing, and exactly how much time should occur between learning sessions is less critical. Teachers and learners should strive to space information across multiple days at long enough intervals that encourage challenging retrieval conditions—i.e., "desirable difficulties—but these intervals can be flexible and adjusted according to course schedules and the specific material being learned.

Should spacing schedules always be the same?

When students learn information across several sessions, should time in-between the sessions increase, decrease, or stay the same? Research shows that slight differences in the timing between sessions does not have a large effect on learning. Students can complete two lessons with one day in-between, with five days in-between, and so on. Compared to learning the information in a single longer session, spacing benefits learning regardless of whether the time between lessons is equal or non-equal.

How many spaced sessions should there be?

Again, the more, the better. For long-term durable learning, teachers and learners should strive to re-visit information over spaced time intervals as many times as possible. The exact number of spacing sessions that can be incorporated, and the time intervals in-between, might depend on the particular course and information being learned. The good news is, spacing benefits learning regardless of how many sessions there are—making it a flexible and adaptive tool that can be tailored to any learning situation—and benefits learning to a greater extent the more it can be utilized.[4]

[4] Pooja K. Agarwal, *How to Use Spaced Retrieval*, pp. 10–11.

Interleaved Practice

> "Interleaved practice is simply a set of problems mixed in a certain way. Practice problems are interleaved if the problems are arranged so that consecutive problems cannot be solved by the same strategy."[5]

Which of the samples are examples of interleaved practice? How do you know?

Sample 1

For problems 1–4, write the number in scientific notation.

1. 600,000
2. 57,500
3. $-8{,}095{,}000$
4. 892

Sample 2

1. Write the number 5.75×10^4 in standard form.
2. Write $-8{,}095{,}000$ in scientific notation.

For problems 3–6, evaluate.

3. $-9 + 3$
4. $-9 - 3$
5. $-9(3)$
6. $-9 \div 3$

Sample 3

1. Evaluate $-9 + 3$.
2. Write $-8{,}095{,}000$ in scientific notation.
3. Solve the equation $-5x + 2 = 7$.
4. Find the edge length of a cube that has a volume of 343 in^3.

[5] Pooja K. Agarwal, Interleaved Mathematics Practice, p. 2.

Closing

1. What retrieval practice strategies enhance long-term learning? Why do these strategies work?

2. What are the benefits of implementing spaced and interleaved practices in your classroom?

3. How can you implement spaced and interleaved practices in your classroom?

Additional Reading

1. How to use Retrieval Practice to Improve Learning
   http://pdf.retrievalpractice.org/RetrievalPracticeGuide.pdf

2. How to use Spaced Retrieval Practice to Boost Learning
   http://pdf.retrievalpractice.org/SpacingGuide.pdf

3. Interleaved Mathematics Practice
   http://pdf.retrievalpractice.org/InterleavingGuide.pdf

4. *Make it Stick: The Science of Successful Learning* by Peter C. Brown, Henry L. Roediger, III, and Mark A. McDaniel

Works Cited

Agarwal, Pooja K. and Shana K. Carpenter. *How to Use Spaced Retrieval Practice to Boost Learning* (Iowa State University: Retrieval Practice, 2020). http://pdf.retrievalpractice.org/SpacingGuide.pdf.

Agarwal, Pooja K., Robert F. Dedrick, and Doug Rohrer. *Interleaved Mathematics Practice Giving Students a Chance to Learn What They Need to Know*. http://pdf.retrievalpractice.org/InterleavingGuide.pdf.

Agarwal, Pooja K., Henry L. Roediger, III, Mark A. McDaniel, and Kathleen B. McDermott. *How to Use Retrieval Practice to Improve Learning* (Washington University in St. Louis: Retrieval Practice, 2020). http://pdf.retrievalpractice.org/RetrievalPracticeGuide.pdf.

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Credits