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Numbers in Scientific Calculations

Lesson 1.1 Learning Chemistry

What does science tell us about the most effective ways to study?

1. **In the sciences, the goal of learning is to solve problems.** Your brain solves problems using information from your environment and from your memory. The brain contains different types of memory, including
   - **working memory (WM)**, where you think by processing information; and
   - **long-term memory (LTM)**, where the brain stores information you have learned.
2. **Problem solving depends on well-memorized information.** A key discovery of recent research in cognitive science is that working memory can hold and process essentially *unlimited* knowledge that one is able to recall quickly from long-term memory but can hold and process only a few small elements that have *not* previously been memorized. During initial learning, a primary goal is to move new knowledge into LTM so that it can then be linked to other knowledge.

3. **Reliably moving knowledge into LTM** requires *repeated thought* about the meaning of new information, *effort* at recalling new facts, and *practice* in applying new skills.
4. **"Automaticity" in recall of fundamentals** is the central strategy to overcome limitations in working memory. When knowledge can be recalled quickly and accurately, more space in WM is available both for processing and for noting the associations within knowledge that build conceptual understanding.
5. **Memorizing standard algorithms** (stepwise procedures) is another way around the "processing bottleneck" in WM.
6. **Concepts are crucial.** Your brain constructs "conceptual frameworks" to judge when information should be recalled. Frameworks are built by practice in applying new knowledge to a variety of problems.
7. **"You can always look it up" is a poor strategy for problem solving.** The more information you must stop to look up, the more difficult it is for WM to manage the steps needed to solve a complex problem.

Moving Knowledge into Memory

How can you promote the retention of needed fundamentals in LTM? The following strategies are recommended by cognitive scientists:

1. **Learn incrementally** (in small pieces). The brain is limited in how much new memory it can construct in a short amount of time. In learning, *steady* wins the race.
2. **Overlearn.** If you practice recalling new information only one time, it will tend to remain in memory for only a few days. *Repeated* practice to perfection (called *overlearning*) builds reliable recall.
3. **Space your learning.** To *retain* what you learn, 20 minutes of study spaced over 3 days ("distributed practice") is more effective than 1 hour of study for 1 day. Study by "massed practice" (cramming) tends not to "stick" in LTM.
4. **Focus on core skills.** The facts and processes you should practice most often are those needed most often in a discipline.
5. **Effort counts.** Experts in a field usually attribute their success to "hard work over an extended period of time" rather than talent.
6. **Self-testing builds memory.** Practicing recall (such as by use of flashcards) and *then* solving problems is more effective than highlighting or re-reading notes or texts.
7. **Use parallel processing.** To remember new knowledge, listen, observe, recite, write, and practice recall. Your brain stores multiple *types* of memory. Multiple cues help you to recall steps and facts needed to solve a problem.
8. **Get a good night's sleep.** While you sleep, your brain reviews the experience of your day to decide what to store in LTM. Sleep promotes retention of what you learn.

For more on the science of learning, see *Cognition: The Thinking Animal* by Daniel Willingham (Prentice Hall, 2007) and *Make It Stick: The Science of Successful*

Learning by Peter C. Brown, Henry L. Roediger III, and Mark A. McDaniel (Harvard University Press, 2014).

PRACTICE

Answer these questions in your notebook:

1. What is "overlearning"?
2. When is "working memory" limited?
3. Which better promotes long-term learning: "massed" or "distributed" practice?

Lesson 1.2 Numeracy

Before you begin this lesson, read "Note to Students" on page 000.

Mental Arithmetic

Research has found that one of the best predictors of success in first-year college chemistry is the ability to solve simple mathematical calculations without a calculator. In part, this is because if you can recall "math facts" quickly from memory, the many relationships in science that are based on simple whole-number ratios make sense. In addition, speed matters in working memory. Fast recall of fundamentals leaves space for attention to the "science side" of demonstrations and calculations.

PRACTICE A

Find a device that measures how long it takes to complete a task in seconds (such as a stopwatch or digital timer on a phone or computer). To learn to use the device, *practice* until you can reliably time "counting to 30 in your head." Then:

1. Time how long it takes, in seconds, to write answers to these eight **addition** problems. Go as *fast* as you can with accuracy.

7 + 4 =	5 + 9 =	3 + 7 =	9 + 7 =
5 + 8 =	7 + 5 =	8 + 7 =	11 + 6 =

   Record your time: _____ seconds

2. Time how long it takes to write answers to these **subtraction** problems as fast as you can.

9 − 4 =	12 − 9 =	11 − 5 =	10 − 3 =
12 − 7 =	9 − 5 =	12 − 3 =	15 − 4 =

   Record your time: _____ seconds

(continued)