CHAPTER 3

MEMORY, RETENTION, AND LEARNING

The multimedia of modern memory devices free us of the necessity to remember vast areas of facts and processes, liberating, presumably, great numbers of neurons and their synapses to other purposes.

— Stephen Rose, *The Making of Memory*

Chapter Highlights: This chapter probes the nature of memory. It explains why our ability to retain information varies within a learning episode and with the teaching method used. It also discusses the value and dangers of practice and techniques for increasing the capacity of working memory.

Memory Makes Us Unique

Memory gives us a past and a record of who we are and is essential to human individuality. Without memory, life would be a series of meaningless encounters that have no link to the past and no use for the future. Memory allows individuals to draw on experience and use the power of prediction to decide how they will respond to future events.

For all practical purposes, the capacity of the brain to store information is unlimited. That is, with about 100 billion neurons, each with thousands of dendrites, the brain will hardly run out of space to store all that an individual learns in a lifetime.[7] Learning is the

7. This poses an interesting question: Why is there so much space if we will never fill it? One theory holds that primitive humans needed to make many decisions each day for their survival. Therefore, solving critical problems daily using higher-order thinking resulted in the evolution of a highly-developed cerebrum.

process by which we acquire new knowledge and skills; memory is the process by which we retain the knowledge and skills for the future. Most of what we have in the cognitive belief system, we have learned. Investigations into the neural mechanisms required for different types of learning are revealing more about the interactions between learning new information, memory, and changes in brain structure. As muscles improve with exercise, the brain seems to improve with use. While learning does not increase the number of brain cells, it does increase their size, their branches, and their ability to form more complex networks.

The brain goes through physical and chemical changes when it stores new information as the result of learning. Storing gives rise to new neural pathways and strengthens existing pathways. Thus, every time we learn something, our long-term storage areas undergo anatomical changes that, together with our unique genetic makeup, constitute the expression of our individuality.

How Memory Forms

What is a memory? Is it actually located in a piece of the brain at a specific spot? Are memories permanent? How does the brain manage to store a lifetime of memories in an organ the size of a melon? The definitive mechanism for memory is still elusive. Nevertheless, neuroscientists have discovered numerous mechanisms that occur in the brain that, taken together, define a workable hypothesis about memory formation.

The Memory Trace

You will recall from Chapter 1 that nerve impulses travel down the axon to the gap, or synapse, where neurotransmitter chemicals are released (Figure 3.1). These chemicals cross the synapse to the dendrite of the other neuron. The dendrites are covered with little bumps, called spines, that contain chemical receptor sites. As the chemical messages enter the spines, they may spark a series of electrochemical reactions that cause this second neuron to generate a signal or "fire." The reaction causes more receptor sites to form on the spines. The next time neurotransmitters cross that particular synapse, the spines will take in more of these chemicals and the stimulation will be stronger, ultimately forming a new memory trace, or *engram.* These individual traces associate and form networks so that whenever one is triggered, the whole network is strengthened, thereby consolidating the memory and making it more easily retrievable.

> ***The brain goes through physical and chemical changes each time it learns.***

Memories are not stored intact. Instead, they are stored in pieces and distributed in sites throughout the cerebrum. The shape, color, and smell of an orange, for example, are categorized and stored in different sets of neurons. Activating these sites simultaneously brings together a recollection of our thoughts and experiences involving an orange. Exactly how this happens is still a mystery.

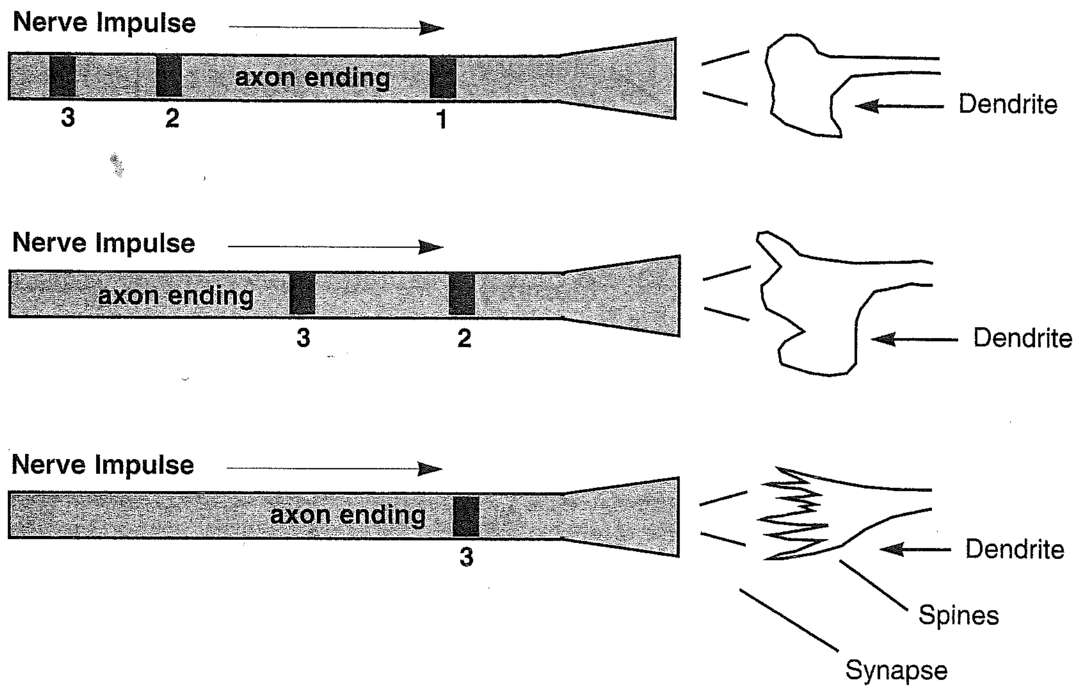
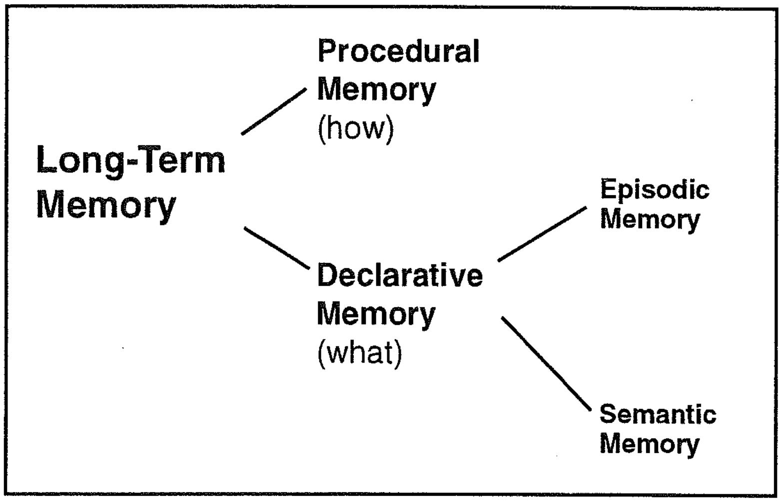


***Figure** 3.1. A memory trace is formed when repeated stimulation of the same neural pathway by nerve impulses causes the spines to form more receptors for neurotransmitters.*

There is also some evidence that the brain stores an extended experience in more than one network. Which sites to select for storage could be determined by the number of associations that the brain makes between the new learning and past learnings. The more connections that are made, the more understanding and meaning the learner can attach to the new learning, and the more likely it is that it will be stored in different networks. This process now gives the learner multiple opportunities to retrieve the new learning.

Persistence in Working and Long-Term Memories

When the signal repetitions along the axon are few, then the spines formed at the affected synapses are too few and too small to associate. This, then, results in an essentially electrochemical reaction and may explain why information in working memory usually does not persist longer than a few hours. If there are many repetitions of the impulse traveling along the neural pathway (through rehearsal and practice), then many larger spines are formed so that there are anatomical changes at the synapses and the memory trace persists.



Types of Long-Term Memory

Attempting to use the observable behaviors of memory to identify different types is a difficult task. Neuroscientists are not in total agreement with psychologists as to the characteristics, including time, that clearly describe the different aspects of long-term memory. Nonetheless, there is considerable agreement on some types, and their description is important to understand before setting out to design learning activities.

Procedural memory refers to remembering *how* to do something, like riding a bicycle, driving a car, swinging a golf club, and tying a shoelace. As practice of the skills continues, these memories become more efficient and can be performed with little conscious thought or recall. Procedural memories are processed primarily by the cerebellum.

Declarative memory describes the remembering of names and objects, as in where I live and the kind of car I own, and are processed by the hippocampus and cerebrum.

We seem to store these types of memories differently. Studies (Rose, 1992) of brain-damaged and amnesia victims show that they may still be perfectly capable of riding a bicycle (procedural) without remembering the name, bicycle, or when they learned to ride (declarative). Procedural and declarative memory seem to be stored in different regions of the brain, and declarative memory can be lost while procedural is spared.

Declarative memory can be further divided into episodic and semantic. Episodic memory refers to the memory of events in one's own life history, while semantic memory is knowledge of facts and data that is independent of that history. A veteran knowing that there was a Vietnam War in the 1970s is semantic memory; remembering his experiences in that war is episodic memory.

How the learner processes new information has a great impact on the quality of what is learned and is a major factor in determining whether and how it will be retained. Memories, of course, are more than just information. They represent fluctuating patterns of associations and connections across the brain from which the individual extracts order and meaning. Studies of memory reveal intriguing patterns that suggest strategies teachers and learners can use to improve the retention and retrieval of learning.

Retention of Learning

Retention refers to the process whereby long-term memory preserves a learning in such a way that it can locate, identify, and retrieve it accurately in the future. As explained earlier, this is an inexact process influenced by many factors, including the length and type of rehearsal that occurred, the critical attributes that may have been identified, the student's learning style, and, of course, the influence of prior learnings.

The information processing model in Chapter 2 identifies some of these factors and sets the stage for finding ways to transfer what we know into daily classroom practice. Let us look more specifically at the way the brain processes and retains information during a learning episode, how the nature of that processing affects the degree of retention, and how the degree of retention varies with the length of the episode.

Rehearsal

The assignment of sense and meaning to new learning can occur only if the learner has adequate time to process and reprocess it. This continuing reprocessing is called rehearsal and is a critical component in the transference of information from working memory to long-term storage. The concept of rehearsal is not new. Even the Greek scholars of 400 BC knew its value. They wrote:

> *Repeat again what you hear; for by often hearing and saying the same things, what you have learned comes complete into your memory.*
>
> — from the *Dialexeis*

Two major factors should be considered in evaluating rehearsal: The amount of time devoted to it, which determines whether there is both initial and secondary rehearsal, and the type of rehearsal carried out, which can be rote or elaborative.

Time for Initial and Secondary Rehearsal

Time is a critical component of rehearsal. Initial rehearsal occurs when the information first enters working memory. If the learner cannot attach sense or meaning, and if there is no time for further processing, then the new information is likely to be lost. Providing sufficient time to go beyond the initial processing to secondary rehearsal allows the learner to review the information, to make sense of it, to elaborate on the details, and to assign value and relevance, thus increasing significantly the chance of long-term storage. When done at the end of a learning episode, this rehearsal is called closure.

Students carry out initial and secondary rehearsal at different rates of speed and in different ways, depending on the type of information in the new learning and their learning styles. As the learning task changes, learners automatically shift to different patterns of rehearsal.

Rote and Elaborative Rehearsal

Rote Rehearsal. This type of rehearsal is used when the learner needs to remember and store information exactly as it is entered into working memory. This is not a complex strategy, but it is necessary to learn information or a skill in a specific form or sequence. We use rote rehearsal to remember a poem, the lyrics and melody of a song, multiplication tables, telephone numbers, and steps in a procedure.

Elaborative Rehearsal. This type of rehearsal is used when it is not necessary to store information exactly as learned, but when it is more important to associate the new learnings with prior learnings to detect relationships. This is a more complex thinking process in that the learner reprocesses the information several times to make connections to previous learnings and assign meaning. Students use rote rehearsal to memorize a poem, but elaborative rehearsal to interpret its message. When students get very little time for, or training in, elaborative rehearsal, they resort more frequently to rote rehearsal for nearly all processing. Consequently, they fail to make the associations or discover the relationships that only elaborative rehearsal can provide. Also, they continue to believe that learning is merely the recalling of information as learned rather than its value for generating new ideas, concepts, and solutions.

There is almost no long-term retention without rehearsal.

Test Question No. 4: *Increased time on task increases retention of new learning.*

Answer: *False. Simply increasing a student's time on a learning task does not guarantee retention if the student is not allowed the time and help to personally interact with the content through rehearsal.*

When deciding on how to use rehearsal in a lesson, teachers need to consider the time available as well as the type of rehearsal appropriate for the specific learning objective. Keep in mind that rehearsal only contributes to, but does not guarantee that information will transfer into long-term storage. But there is almost no long-term retention *without* rehearsal.

Retention During a Learning Episode

When an individual is processing new information, the amount of information retained depends, among other things, on when it is presented during the learning episode. At certain time intervals during the learning we will remember more than at other intervals. Try a simple activity that Madeline Hunter devised to illustrate this point. You will need a pencil and a timer. Set the timer to go off in 12 seconds. When you start the timer, look at the list of 10 words on the next page. When the timer sounds, cover the list and write as many of the 10 words as you remember on the lines to the right of the list. Write each word on the line that represents its position on the list, i.e., the first word on line one, etc. Thus, if you cannot remember the eighth word, but you remember the ninth, write it on line number nine.

Ready? Start the timer and stare at the word list for 12 seconds. Now cover the list and write the words you remember on the lines to the right. Don't worry if you did not remember all the words. Turn to your list again and circle the words that were correct. To be correct, they must be spelled correctly and be in the proper position on the list. Look at the circled words. Chances are you remembered the first 3–5 words (lines 1 through 5) and the last 1–2 words (lines 9 and 10), but had difficulty with the middle words (lines 6–8). Read on to find out why.

KEF	1. ________
LAK	2. ________
MIL	3. ________
NIR	4. ________
VEK	5. ________
LUN	6. ________
NEM	7. ________
BEB	8. ________
SAR	9. ________
FIF	10. ________

Primacy-Recency Effect

Your pattern in remembering the word list is a common phenomenon and is referred to as the primacy-recency effect. In a learning episode, we tend to remember best that which comes first, and remember second best that which comes last. We tend to remember least that which comes just past the middle of the episode. This is not a new discovery. Ebbinghaus published the first studies on this phenomenon in the 1880s.

The information processing model in Chapter 2 helps to explain this phenomenon. The first items of new information are within the working memory's functional capacity, command our attention, and are likely to be retained. The later information, however, exceeds the capacity and is dropped. As the learning episode concludes, items in working memory are sorted or chunked to allow for additional processing of the arriving final items.

Figure 3.2 shows how the primacy-recency effect influences retention during a 40-minute learning episode.[8] The times are approximate and averages. Note that it is a bimodal curve, each mode representing the degree of greatest retention during that time

8. Many of the original studies used for these graphs can be found in E. J. Thomas, "The Variation of Memory with Time for Information Appearing During a Lecture," *Studies in Adult Education*, April 1972, pp. 57–62.

period. For future reference, I will label the first or primary mode *prime-time-1,* and the second or recency mode *prime-time-2.* Between these two modes is the time period in which retention during the lesson is least. I will refer to that area as the *down-time.* This is not a time when no retention takes place, but a time when it is more difficult for retention to occur.

> ***During a learning episode, we remember best that which comes first, second best that which comes last, and least that which comes just past the middle.***

Implications for Teaching

Teach New Material First

There are important implications of the primacy-recency effect for teaching a lesson. The learning episode begins when the learner focuses on the teacher with intent to learn. New information or skills should be taught first, during prime-time-1, since it is most likely to be remembered. Keep in mind that the students will remember almost any information coming forth at this time. It is important, then, that only correct information be presented. This is not the time to be searching for what students may know about something. I remember watching a teacher of English start a class with, "Today, we are

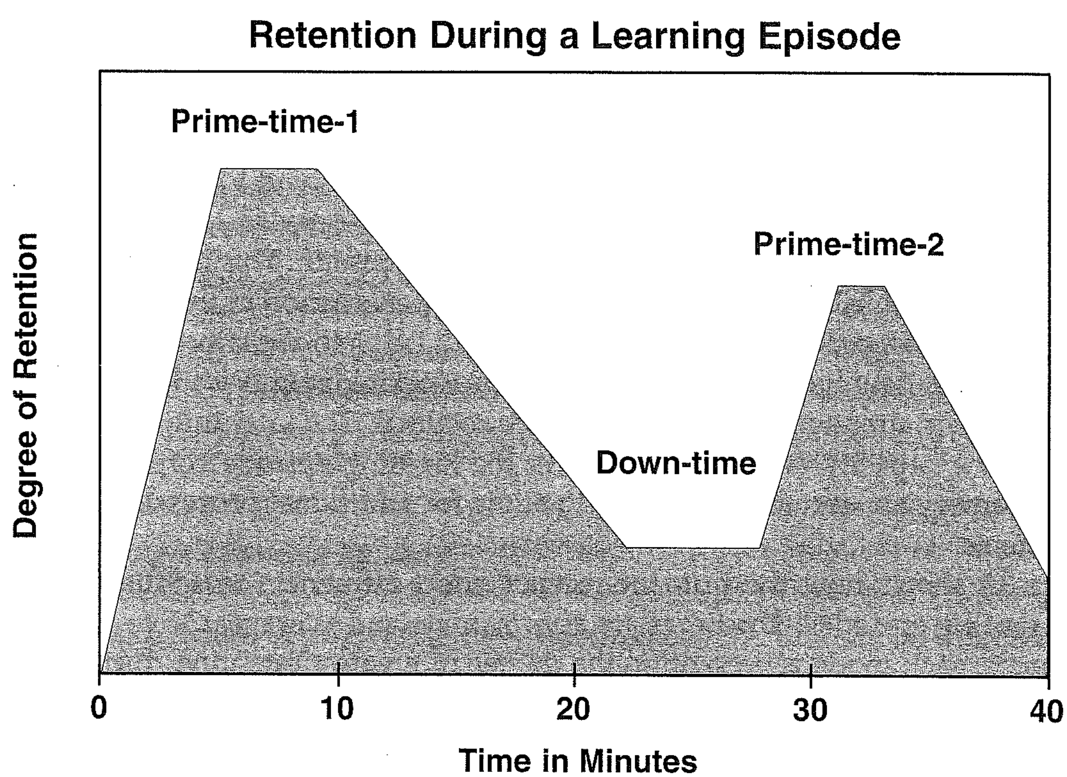


Figure 3.2. *The degree of retention varies during a learning episode.*

going to learn about onomatopoeia. Does anyone have an idea what that is?" After several wrong guesses, he finally defined it. Regrettably, those same wrong guesses appeared in the follow-up test. And why not? They were mentioned during the most powerful retention position, prime-time-1.

The new information or skill being taught should be followed by practice or review during the down-time. At this point, the information is no longer new and the practice helps the learner organize it for further processing. Closure should take place during prime-time-2, since this is the second most powerful learning position and an important opportunity for the learner to determine sense and meaning.

When you have the students' focus, teach the new information. Don't let prime time get contaminated with wrong information.

Adding these activities to the graph in Figure 3.3 shows how we can take advantage of research on retention to design a more effective lesson.

Misuse of Prime Time

Even with the best of intentions, teachers with little knowledge of the primacy-recency effect can do the following: After getting focus by telling the class the day's lesson objective, the teacher takes attendance, distributes the previous day's homework, collects

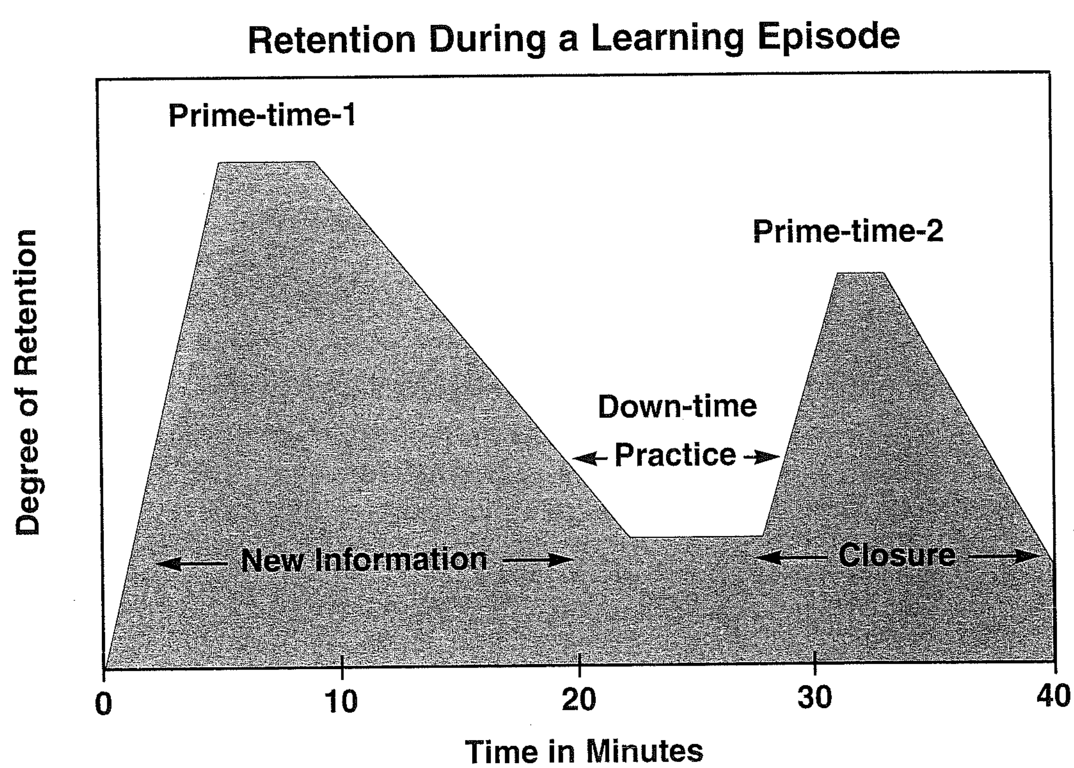


Figure 3.3. New information and closure are best presented during the prime-time periods. Practice is appropriate for the down-time segment.

that day's homework, requests notes from students who were absent, and reads an announcement about a club meeting after school. By the time the teacher gets to the new learning, the students are already at the down-time. As a finale, the teacher tells the students that they were so well-behaved during the lesson that they can do anything they want during the last five minutes of class (that is, during prime-time-2) as long as they are quiet. I have observed this scenario, and I can attest that the next day those students remembered who was absent and why, which club met after school, and what they did at the end of the period. The new learning, however, was difficult to remember because it was presented at the time of least retention.

Retention Varies with Length of Teaching Episode

Another fascinating characteristic of the primacy-recency effect is that the proportion of prime-times to down-time changes with the length of the teaching episode. Look at Figure 3.4 below. Note that during a 40-minute lesson, the two prime-times total about 30 minutes, or 75 percent of the teaching time. The down-time is about 10 minutes, or 25 percent of the lesson time. If we double the length of the learning episode to 80 minutes (Figure 3.5), the down-time increases to 30 minutes or 38 percent of the total time period. As the lesson time lengthens, the percentage of down-time increases faster than for prime-time. The information is entering working memory faster than it can be sorted or checked, and accumulates. This cluttering interferes with the sorting and chunking pro-

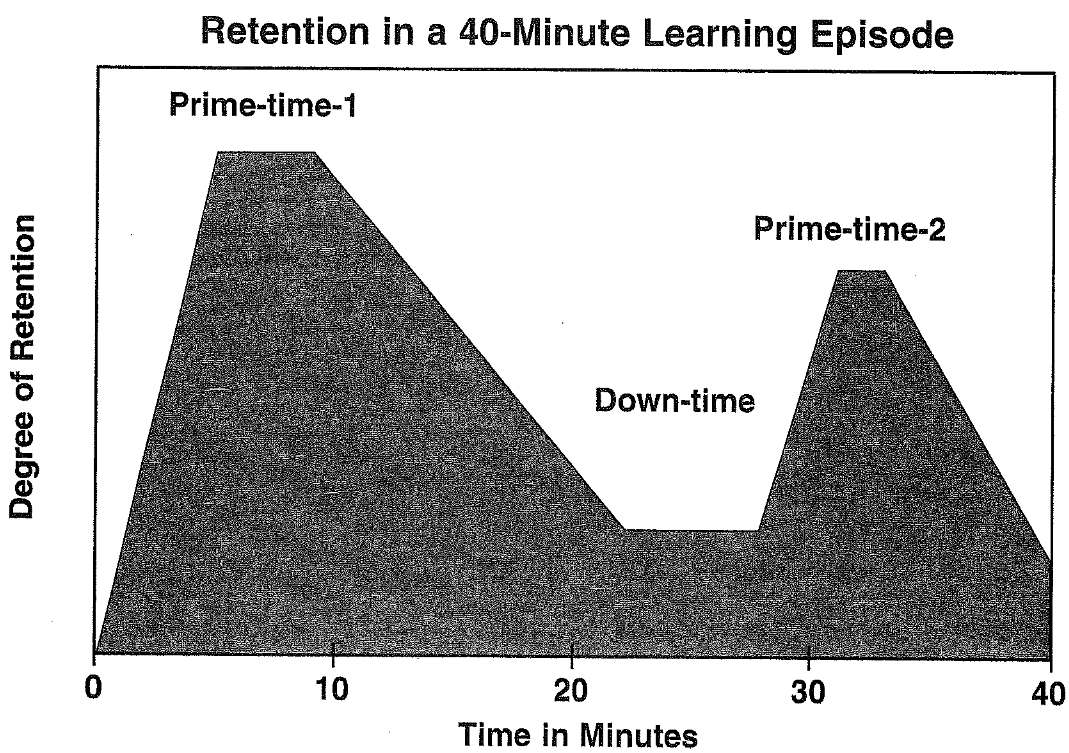


Figure 3.4. *Degree of retention during a 40-minute lesson.*

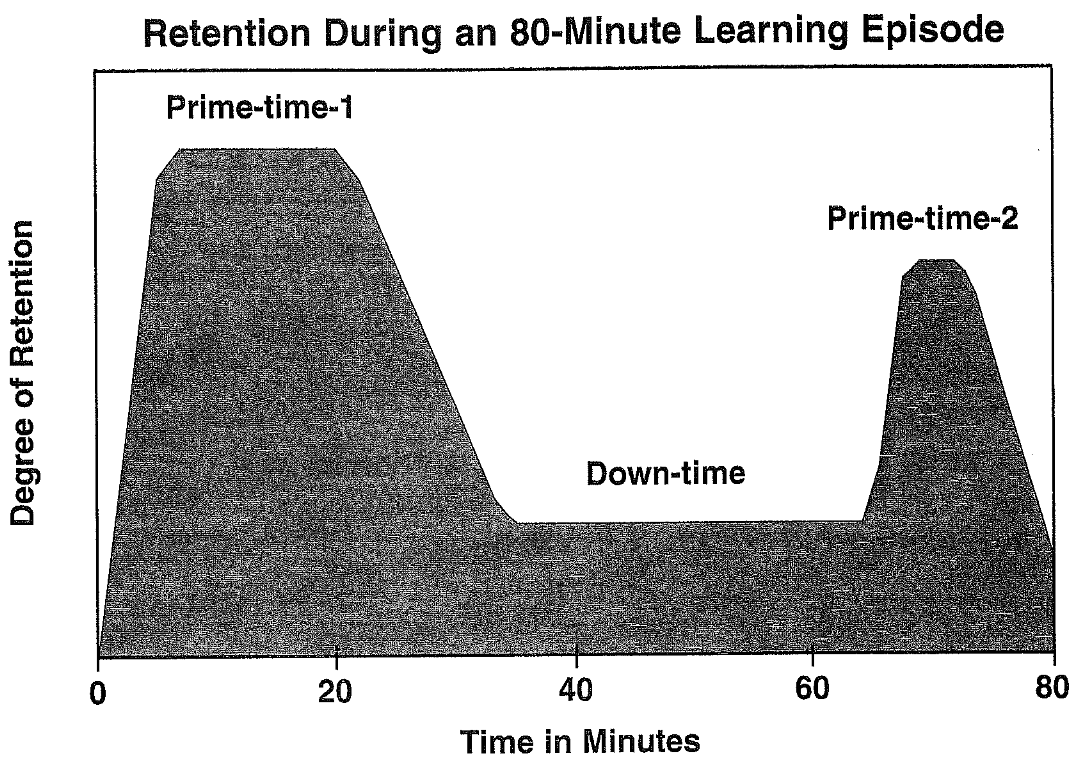


Figure 3.5. Degree of retention during an 80-minute lesson.

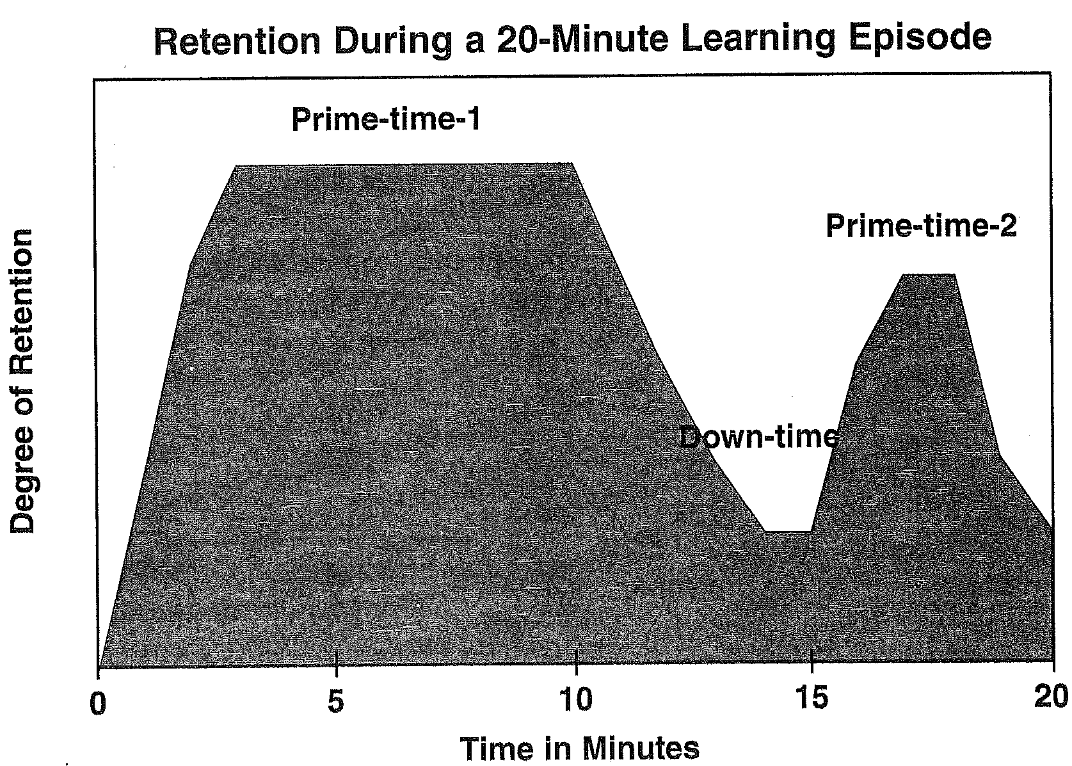


Figure 3.6. Degree of retention during a 20-minute lesson.

AVERAGE PRIME AND DOWN-TIMES IN LEARNING EPISODES				
	Prime-Times		Down-Time	
Episode Time	Total Number of Minutes	Percent of Total Time	Number of Minutes	Percent of Total Time
20 min.	18	90	2	10
40 min.	30	75	10	25
80 min.	50	62	30	38

cesses and reduces the learner's ability to attach sense and meaning, thereby decreasing retention. Think back to some of those college classes that lasted for two hours. After the first 20 minutes or so, didn't you find yourself concentrating more on taking notes rather than on learning what was being presented?

Figure 3.6 shows what happens when we shorten the learning time to 20 minutes. The down-time is about 2 minutes or 10 percent of the total lesson time. As we shorten the learning episode, the down-time decreases faster than the prime-times. This research indicates that there is a higher probability of effective learning taking place if we can keep the learning episodes short and, of course, meaningful. Thus, teaching two 20-minute lessons provides 20 percent more prime-time (approximately 36 minutes) than one 40-minute lesson (approximately 30 minutes). Note, however, that a time period shorter than 20 minutes usually does not give the learner's brain sufficient time to determine the pattern and organization of the new learning, and is thus of little benefit.

The table above summarizes the approximate number of minutes in the prime-times and down-times of the learning cycle for episodes of 20, 40, and 80 minutes.

Figure 3.7 shows the gain in prime time that results from teaching two 20-minute lessons over one 40-minute lesson. Remember that the times are averages over many episodes. Nonetheless, these data confirm what we may have suspected: More retention occurs when lessons are shorter.

Retention Varies with Teaching Method

The learner's ability to retain information is also dependent on the type of teaching method used. Some methods result in more retention of learning than others. The learning pyramid in Figure 3.8, devised by the National Training Laboratories of Bethel, Maine, comes from studies on retention of learning after students were exposed to

> ***Lecture continues to be the most prevalent teaching mode in secondary and higher education, despite overwhelming evidence that it produces the lowest degree of retention for most learners.***

different teaching methods. The pyramid shows the percentage of new learning that students can recall after 24 hours as a result of being taught *primarily* by the teaching method indicated. The percentages are not additive. At the top of the pyramid is lecture—the teaching method that results in an average retention of only 5 percent of learn-

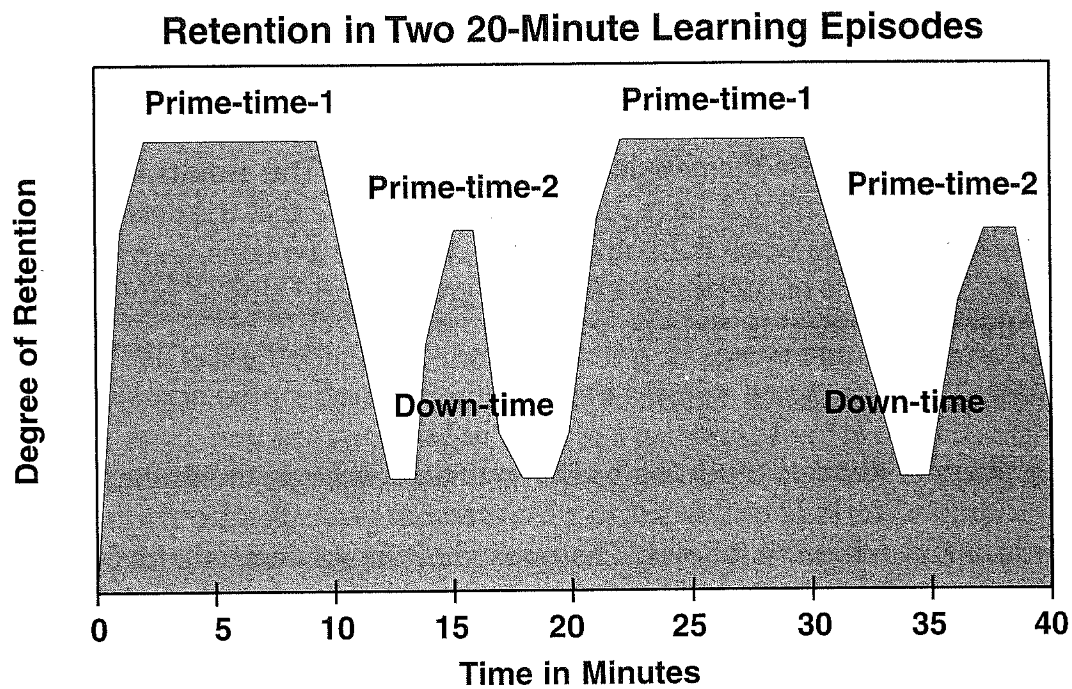


***Figure** 3.7. The graph illustrates how two 20-minute lessons are likely to result in more prime-time retention than one 40-minute lesson.*

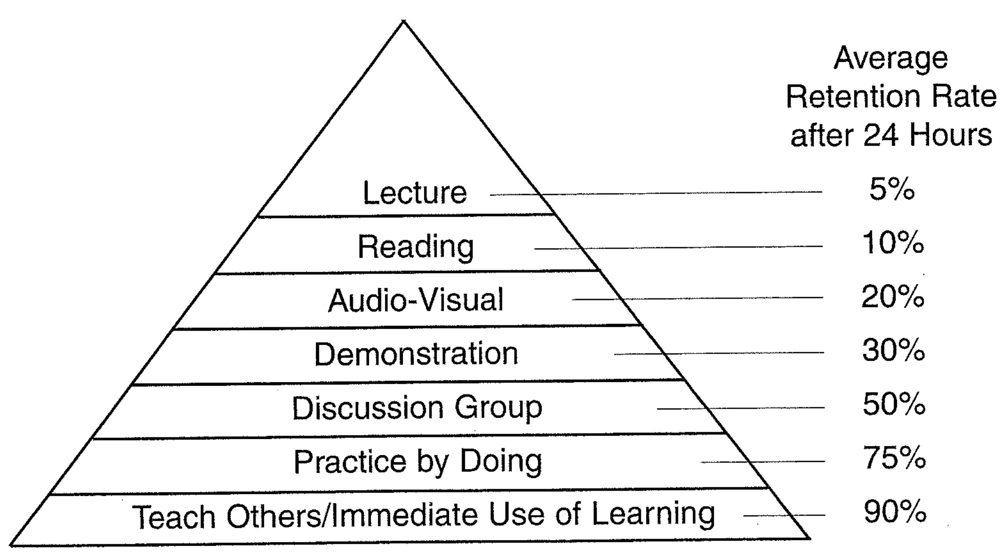


***Figure** 3.8. The learning pyramid shows the average percentage of retention of material after 24 hours for each of these instructional methods.*

ing after 24 hours. This result is not surprising since lecture usually involves little student active participation or mental rehearsal. In this format, the teacher is telling and the students are listening just enough to convert the teacher's auditory and visual input into written notes. Rote rehearsal predominates and elaborative rehearsal is minimal or nonexistent. Despite the impressive amount of evidence about how little students retain from lecture, it continues to be the most prevalent mode of teaching, especially in secondary and higher education.

Moving down the pyramid, students become more involved in the learning process, and retention increases. The method at the bottom of the pyramid involves having the students teach others or use the new learning immediately. This results in over 90 percent retention after 24 hours. We have known for a long time that the best way to learn something is to prepare to teach it. In other words, whoever explains, learns. This is one of the major components of cooperative learning groups and helps to explain the effectiveness of this instructional technique.

Retention Through Practice

Practice refers to learners repeating a skill over time. It begins with the rehearsal of the new learning in working memory. Later, the memory is recalled from long-term storage and additional rehearsal follows. The quality of the rehearsals and the learner's knowledge base will largely determine the outcome of each practice.

The old adage that "practice makes perfect" is rarely true. It is very possible to practice the same skill repeatedly with no increase in achievement or accuracy of application. Think of the people you know who have been driving, cooking, or even teaching for many years with no improvement in their skills. Why is this? How is it possible for one to continuously practice a skill with no resulting improvement in performance?

Conditions for Successful Practice

For practice to *improve* performance, three conditions must be met (Hunter, 1982):

1. The learner must have all the knowledge necessary to understand the options available in applying the new knowledge or skill.

2. The learner must understand the steps in the process of applying the knowledge to deal with a particular situation.

3. The learner must be able to analyze the results of that application and know what variables need to be manipulated to improve performance in the future.

Teachers help learners meet these conditions when they:

- Start by selecting the smallest amount of material that will have maximum meaning for the learner.

- Model the application process step by step.
- Insist that the practice occur in their presence over a short period of time while the student is focused on the learning.
- Watch the practice and provide the students with prompt and specific feedback on what variable needs to be altered to correct and enhance the performance.

This strategy leads to perfect practice, and "Perfect practice makes perfect."

Practice and Feedback

Practice does make permanent, thereby aiding in the retention of learning. Consequently, we want to ensure that students practice the new learning correctly from the beginning. This early practice (referred to as *guided practice*), then, is done in the presence of the teacher who can now offer corrective feedback to help students analyze and improve their practice. When the practice is correct, the teacher can then assign *independent practice,* in which the students can rehearse the skill on their own to enhance retention.

Teachers should avoid giving students independent practice before guided practice. Since practice makes permanent, allowing students to rehearse something for the first time while away from the teacher is very risky. If they unknowingly practice the skill incorrectly, then they will learn the incorrect method well! This will present serious problems for both the teacher and learner later on because it is very difficult to change a skill that has been practiced and remembered, even if it is not correct.

Practice Over Time

Hunter (1982) suggested that teachers use two different types of practice over time, massed and distributed. Practicing a new learning during time periods that are very close together is called *massed practice.* This produces fast learning, as when you may mentally rehearse a new telephone number if you are unable to write it down.

Teachers provide massed practice when they allow students to try different examples of applying new learning in a short period of time. Cramming for an exam is an example of massed practice. Material can be quickly chunked into working memory, but can also be quickly dropped or forgotten if more sustained practice does not follow soon. This happens because the material has no further meaning and the need for long-term retention disappears.

> ***Practice does not make perfect. Practice makes permanent. However, perfect practice makes perfect!***

Sustained practice over time, called *distributed practice,* is the key to retention. If you want to remember that new telephone number later on, you will need to use it repeatedly over time. Thus, practice that is dis-

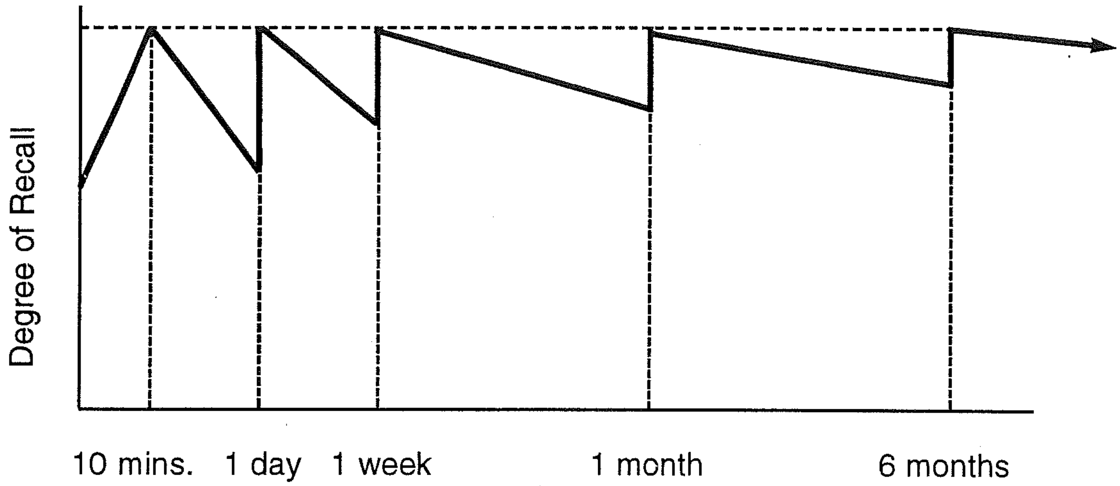


Figure 3.9. Practice over time (distributed practice) increases the degree of recall of learnings.

tributed over longer periods of time sustains meaning and consolidates the learnings into long-term storage in a form that will ensure accurate recall and applications in the future. The graph in Figure 3.9 shows that recall after periodic review improves over time. This is the reason behind the idea of the spiral curriculum whereby critical information and skills are reviewed at regular intervals within and over several grade levels.

Effective practice, then, starts with massed practice for fast learning and proceeds to distributed practice later for retention. This means that the student is continually practicing previously learned skills throughout the year. Each test should not only test new material, but should also allow students to practice older learnings. This method not only helps in retention, but reminds students that the learnings will be useful for the future and not just for the time when they were first learned.

Intelligence and Retrieval

Intelligence

Multiple Intelligences. Our modern notion of what constitutes human intelligence is growing increasingly complex. At the very least, it represents a combination of varied abilities and skills. The work of researchers such as Howard Gardner and Robert Sternberg has changed our view of intelligence from a singular entity to a multi-faceted aptitude that varies even within the same person. Gardner (1983) is convinced that at least seven different intelligences exist for each individual.[9] This theory suggests that at the core of each intelligence is an information-processing system (similar perhaps to that in

9. Gardner's seven intelligences are: musical, logical-mathematical, spatial, bodily-kinesthetic, linguistic, interpersonal, and intrapersonal.

Chapter 2) unique to that intelligence. The intelligence of an athlete is different from that of a musician or physicist. He also suggests that each intelligence is semi-autonomous. A person who has abilities in athletics but who does poorly in music has enhanced athletic intelligence. The presence or absence of music capabilities exists separately from the individual's athletic prowess.

Working Definition of Intelligence

We need a working definition of intelligence that reflects modern theory and is useful for practitioners. I offer this one: Intelligence is the *rate of learning* something. Although we are defining this complex concept with only three words, we need to understand them thoroughly. "Rate" is the amount of learning per unit of time. "Learning" is acquiring the information or skill through the application level of Bloom's Taxonomy (Chapter 6), so that it can be used to solve problems. Thus, "rate of learning" means the number of units of time one needs to acquire information or a skill at a level that can be used to solve problems correctly. By applying Gardner's concept of multiple intelligences, an individual can acquire different types of learning at different rates. One could learn to play several musical instruments quickly and competently, but have difficulty learning mathematics.

> ***Our modern view of intelligence sees it as a multi-faceted aptitude that varies even within the same individual. It can be defined as the rate of learning something.***

Using the rate of learning as the major criterion implies that intelligence is primarily a matter of neural efficiency. Could it be that intelligence describes the speed of the process whereby the brain eventually learns to use fewer neurons or networks to accomplish a repetitive task? If so, think of the implications this concept has for altering the way we allocate learning time, and design and deliver lessons. It suggests, at the very least, that we should vary learning time to accommodate the task at hand, and move learners to intensive practice as soon as comprehension is established.

Retrieval

It takes less than 50 milliseconds (a millisecond is 1/1000th of a second) to retrieve an item from working memory. Retrieving a memory from long-term storage, however, can be complicated and comparatively time-consuming. The brain uses two methods to retrieve information from long-term storage.

Recognition. Recognition matches an outside stimulus with stored information. For example, the questions on a multiple-choice test involve recognizing the correct answer (assuming the learner stored it originally) among the choices. This method helps explain why even poor students almost always do better than expected on multiple-choice tests.

Recall. Recall is quite different and more difficult. It describes the process whereby cues or hints are sent to long-term memory, which must search and retrieve information from long-term storage, then consolidate and decode it back into working memory.

Both methods require the firing of neurons along the neural pathways to the storage site(s) and back again to working memory. The more frequently we access a pathway, the less likely it is to be obscured by other pathways. Information we use frequently, such as our name and telephone number, are quickly retrieved because the neural impulses to and from those storage sites keep the pathways clear. When the information is moved into working memory, we reprocess it to determine its validity and, in effect, relearn it.

Every time we retrieve something from long-term storage into working memory we relearn it.

The rate at which the retrieval occurs depends on a number of factors, one of which is the system the student used to store the information originally. Students store the same item of information in different networks, depending on how they link the information to their past learnings. These storage decisions affect the amount of time it will take these students to retrieve the information later. This explains why some students need more time than others to retrieve the same information. When teachers call on the first hands that go up, they inadvertently signal to the slower retrievers to stop the retrieval process. This is an unfortunate strategy for two reasons: First, the slower retrieving students feel that they are not getting teacher recognition, thereby lowering their self-concept. Second, by not retrieving the information into working memory, they miss an opportunity to relearn it.

Calling on the first hands that go up signals slower retrievers to stop the retrieval process.

Rates of Learning and Retrieval. In the information processing model in Chapter 2, the rate of learning (our working definition of intelligence) is represented by the data arrows flowing from left to right (from the senses through the perceptual register) to short-term memory and into working memory. The rate of retrieval is represented by the recall arrow moving information from right to left, i.e., from long-term storage to working memory. *These two rates are independent of each other.* This notion is quite different from classic doctrine that holds that the retrieval rate is strongly related to intelligence, and thus anchored in genetic inheritance. The doctrine is further fueled in our society by timed tests and quiz programs that use the speed of retrieving answers as the main criterion for judging success and intelligence. The disclosure that the rate of retrieval is linked to the nature of the learner's storage method—a learned skill—rather than to intelligence is indeed significant. Since it is a *learned* skill, it can be taught. There is now great promise that techniques can be developed for helping us refine our storage methods for faster and more accurate retrieval. Some of those techniques are in the **Practitioner's Corners** at the end of this chapter.

The rate of learning and the rate of retrieval are independent of each other.

Since the rate of learning and the rate of retrieval are independent, individuals can be fast or slow learners, fast or slow retrievers, and every combination in between. While most people tend to fall mid-range, some are at the extremes. Actually, not only have we had experience with learners possessing the extreme combinations of these two rates, but we have (unwittingly) made up

> ***Test Question No. 5:*** *The rate at which a learner retrieves information from memory is closely related to intelligence.*
>
> ***Answer:*** *False. The rate of retrieval is independent of intelligence. It is more closely tied to how and where the information was stored originally.*

labels to describe them. An individual who is a fast learner and a fast retriever we call a *genius*. These students retrieve answers quickly. Their hands go up first. Their responses are almost always correct, and they get reputations as "brains." Teachers call on them when they want to keep the lesson moving.

A fast learner and slow retriever we call an *underachiever*. Teachers usually say to these students, "Come on, John, I know you know this ... keep trying." We often run out of patience and admonish them for not studying enough. A slow learner and fast retriever, we call an *overachiever*. These students may respond quickly, but their answers may be incorrect. Teachers sometimes mistakenly view them as trying too hard to learn something that may be beyond them.

For a slow learner and slow retriever, we have a whole list of uncomplimentary labels. More regrettable is that too often we interpret "slow learner" to mean "unable to learn." What being a slow learner really means is that the student is unable to learn something in the amount of time we have arbitrarily assigned for that learning. All these labels are unfortunate since they perpetuate the mistaken notion that the major factors promoting successful learning are beyond the control of the learner and teacher.

> ***Too often we interpret slow learner to mean unable to learn.***

Chunking

Is it possible to consciously increase the number of items that working memory can handle at one time? The answer is yes, through a process called *chunking*. Chunking occurs when working memory perceives a set of data as a single item, much as we perceive *information* as one word (and, therefore, one item) even though it is composed of 11 separate letters. Going back to the number exercise in Chapter 2, some people may have indeed remembered all 10 digits in the right sequence. These may be people who spend a lot of time on the telephone. When they see a 10-digit number, their experience helps them to group it by area code, prefix, and extension. Thus, they see the second number, 4915082637, as (491) 508–2637, which is in 3 chunks, not 10. Since 3 are within the working memory's functional capacity, they can remember it accurately.

Effect of Experience

Let's take this a step further. Look at the following sentence:

> ***Test Question No. 6:*** *The amount of information a learner can deal with at one time is genetically linked.*
>
> ***Answer:*** *False. The amount of information a learner can deal with at one time is linked to the learner's ability to add more items to the chunks in working memory—a learned skill.*

Grandma is buying an apple.

This sentence has 22 letters, but only five chunks (or words) of information. Since the sentence is one complete thought, most people treat it as just one item in working memory. In this example, 22 bits of data (letters) become one chunk (complete thought). Visual learners probably formed a mental image of a grandmother buying that apple.

Now let's add more information to working memory. Stare at the next sentence below for about 10 seconds. Now close your eyes and try recalling the two sentences.

Hte plpae si edr.

Having trouble with the second? That's because the words make no sense and working memory is treating each of the 13 letters and three spaces as 16 individual items (plus the first sentence as 1 item, for a total of 17). The 5–9 item functional capacity range of working memory is quickly exceeded.

Let's rearrange the letters in each word of the second sentence to read as follows:

The apple is red.

Stare at this sentence for 10 seconds. Now close your eyes again and try to remember the first sentence and this sentence. Most people will remember both sentences since they are now just 2 items instead of 17, and their meanings are related. Experience, once again, helps the working memory decide how to chunk items.

Here's a frequently-used example of how experience can help in chunking information and improving achievement. Get the pencil and paper again. Now stare at the letters below for 10 seconds. Then look away from the page and write them down in the correct sequence and groupings. Ready? Go.

LSDN BCT VF BIU SA

Check your results. Did you get all the letters in the correct sequence and groupings? Probably not, but that's OK. Most people would not get 100 percent by staring at the letters in such a short period of time.

Let's try it again. Same rules: Stare at the letters below for 10 seconds and write the letters down. Ready? Go.

LSD NBC TV FBI USA

How did you do this time? Most people do much better on this example. Now compare the two examples. Note that the letters in both examples are *identical and in the same sequence!* The only difference is that the letters in the second example are grouped or chunked in a way that allows experience to help working memory process and hold the items. Working memory saw the first example as 14 letters plus four spaces (since the grouping was important) or 18 items—much more than its functional capacity. But the second example was quickly seen as only 5 understandable items (the spaces no longer mattered) and thus within the limits of its capacity. Some people may have even paired NBC with TV, and FBI with USA, so that they actually dealt with just three chunks. These examples show the power of experience in remembering—a principle of learning called *transfer,* which we will discuss in the next chapter.

Chunking is a very effective way of enlarging working memory's capacity. It can be used to memorize a long string of numbers or words. Most of us learned the alphabet in chunks—for some it may have been abcd, efg, hijk, lmnop, qrs, tuv, wxyz. Chunking reduced the 26 letters to a smaller number of items that working memory could handle. Even people can be chunked, such as couples (e.g., Romeo and Juliet, Abbott and Costello, Bonnie and Clyde), in which recalling the name of one immediately suggests the name of the other. Master chess players remember the chess board by chunking the individual pieces into meaningful clusters. This reduces the board to a few chunks and leaves room in working memory for additional information and processing. Although working memory has a functional capacity limit as to the number of chunks it can process at one time, there appears to be no limit to the number of items that can be combined into a chunk.

Chunking is an effective way of enlarging working memory's capacity and for helping the learner make associations that establish meaning.

Cramming

Cramming for a test or interview is another example of chunking. The learner loads into working memory as many items as can be identified as needed. Varying degrees of temporary associations are made among the items. With sufficient effort and meaning, the items can be carried in working memory, even for hours, until needed. If the source of the crammed items was outside the learner, that is, from texts or class notes, then it is possible for none of the crammed items to be transferred to long-term storage. This practice (which many of us have experienced) explains how a learner can be conversant and outwardly competent in the items tested on one day (while the items were in working memory) and have little or no understanding of them several days later after they drop out of working memory into oblivion. We cannot recall what we have not stored. See the **Practitioner's Corner** on "Testing Whether Information is in Long-Term Storage" in Chapter 2.

> ***Test Question No. 7:*** *It is usually not possible to increase the amount of information that the working memory can deal with at one time.*
>
> ***Answer:*** *False. By increasing the number of items in a chunk, we can increase the amount of information that our working memory can process simultaneously.*

Forgetting

What happens to memories in long-term storage over time? The answer to this question has now changed because of new research. Until recently, we thought that the storage sites deteriorated naturally over time due to subtle changes in the structure and orientation of the molecules at the dendrite spines located in the memory site synapses. As these changes continued, more of the memory would be distorted or lost, resulting in *forgetting*. Recent studies of brain-damaged patients (Rose, 1992) suggest, however, that forgetting is not due to the deterioration of the memory sites, but more likely to *losing the pathways* to the sites. Apparently, this happens when we do not recall a memory for a long time. The pathway to older learning is obscured by new pathways formed to more recent memories that now interfere with recalling the older memory. The older memory, however, seems to remain unchanged throughout the life of the individual.

Does it make a difference whether forgetting is the deterioration of the memory sites or losing the pathways? Is not the result the same, the inability to recall the memory? Sure, the result *is* the same, but since our understanding of the storage process has changed, so has the method for trying to recall it. We can use a therapy that helps us to find the original pathway, or an alternate pathway, to the memory sites.

Here is an example. Suppose you try to recall the name of the teacher you had when you were in second grade. Unless you have thought recently about that teacher, the pathway to that name has not been used for a long time. It is blocked by newer pathways, and you will have difficulty finding it. The name is still there, but it may take you as long as several days to find it. It will probably come to you when you least expect it.

Another example: Suppose you start thinking about finding an old sweater that you have not seen in several years. If you believe you gave it away, you will not even begin to look for it. That is the same as if you believe that your forgotten memory has been destroyed over time; you will not even try to recall it. On the other hand, if you are con-

> ***Test Question No. 8:*** *Recent research confirms that information in long-term storage deteriorates as we get older.*
>
> ***Answer:*** *False. Pathways to older memory sites get obstructed by newer pathways.*

vinced that the sweater is somewhere in that big attic, then it is just a matter of time before your hunt pays off and you find it. You'll probably start by thinking of the last time you wore it.

This is the same process memory therapy uses with brain-damaged individuals. The therapy helps the patient seek other neural connections to find the original or an alternate pathway to the memory sites. We'll discuss this storage process more in Chapter 4 when we look at the transfer of learnings.

Confabulation

Have you ever been discussing an experience with someone who had shared it with you and started arguing over some of the details? As described earlier, long-term memory is the process of searching, locating, retrieving, and transferring information to working memory. Rote recall, especially of frequently used information, such as your name and address, is actually simple. These pathways are clear and retrieval time is very short. Retrieving more complex and less-frequently used concepts is much more complicated. It requires signaling multiple storage sites through elaborate, cluttered pathways for intermediate consolidation and ultimate decoding into working memory. It is less accurate. First, most do not retain 100 percent of elaborate experiences, such as an extensive vacation. Second, we store parts of the experience in many storage areas.

When retrieving such an experience, the long-term memory may not be able to locate all the events being requested, either because of insufficient time or because they were never retained. In this case, it unconsciously fabricates the missing or incomplete information by selecting the next closest item it can recall. This process is called *confabulation* and occurs because the brain is always active and creative, and seems to abhor incompleteness. It is *not* lying, since confabulation is an unconscious rather than a deliberate process, and the individual believes the fabricated information to be true. This explains why two people who participated in the same experience will recall slightly—or even significantly—different versions of the same event. Neither individual stored 100 percent of the experience. If they stored 90 percent, it would not be the *same* 90 percent for both. Their missing and different 10 percents will be fabricated and will cause each to question the accuracy of the other's memory. The less of the experience remembered, the more the brain must fabricate.

Our brain fabricates information and experiences that we believe to be true.

Over time, the fabricated parts are consolidated into the memory network. As we systematically recall this memory, minor alterations may continue to be made through confabulation. Gradually the original memory is transformed and encoded into a considerably different one that we believe to be true and accurate.

This also happens in the classroom. When recalling a complex learning, the learner is unaware of which parts were missing and, thus, fabricated. The younger the learner, the more inconsistent the fabricated parts are likely to be. The teacher may react by thinking the student is inventing answers intentionally and may discipline accordingly.

Rather, the teacher should be aware of confabulation as a possibility, identify the fabricated parts, and provide the feedback needed to help the student correct the inaccurate material. Through practice, the learner will then incorporate the corrected material into memory and transfer it to long-term storage.

Confabulation has implications for the justice system. This tendency for the brain to fabricate information rather than admit its absence can have serious consequences in court trials where eyewitnesses, under the pressure of testifying, feel compelled to provide complete information. Confabulation also raises questions about the accuracy of witnesses recalling very old memories of unpleasant events, such as a childhood accident or abuse. Experiments done by Loftus (1995) have shown how easy it is to distort a person's recollection of even recent events, or to "implant" memories. In the absense of independent verification, it is impossible to decide what events in the recalled "repressed memory" actually occurred and which are the result of confabulation.

PRACTITIONER'S CORNER

Using Rehearsal To Enhance Retention

Rehearsal refers to the learner's reprocessing of new information in an attempt to determine sense and meaning. It occurs in two forms. Some information items have value only if they are remembered *exactly* as presented, such as the letters and sequence of the alphabet, spelling, poetry, telephone numbers, and the multiplication tables. This is called *rote rehearsal.* Sense and meaning are established quickly and the likelihood of long-term retention is high. Most of us can recall poems and telephone numbers that we learned many years ago.

More complex concepts require the learner to make connections and to form associations and other relationships in order to establish sense and meaning. Thus, the information may need to be reprocessed several times as new links are found. This is called *elaborative rehearsal.* The more senses that are used in this elaborative rehearsal, the more reliable the associations. Thus, when visual, auditory, and kinesthetic activities assist the learner during this rehearsal, the probability of long-term storage rises dramatically. That is why it is important for students to talk about what they are learning *while* they are learning it, and to have visual models as well.

Rehearsal is teacher-initiated and teacher-directed. Recognizing that rehearsal is a necessary ingredient for retention of learning, teachers should consider the following when designing and presenting their lessons:

Rote Rehearsal Strategies

- **Simple Repetition.** For remembering short items (telephone numbers, names, and dates) this is simply repeating a set of items over and over until they can be recalled in correct sequence.

- **Cumulative Repetition.** For longer sets of items (song, poem, list of battles) the learner rehearses the first few items. Then the next set of items in the sequence is added to the first set for the next rehearsal, and so on. To remember a poem of four stanzas, the learner rehearses the first stanza, then rehearses the second stanza alone, then the two together, then rehearses the third stanza, then the three stanzas together, etc.

PRACTITIONER'S CORNER

Using Rehearsal To Enhance Retention – Continued

Elaborative Rehearsal Strategies

- **Paraphrasing.** Students orally restate ideas in their own words, which then become familiar cues for later storage. Using auditory modality helps the learner attach sense, making retention more likely.

- **Selecting and Notetaking.** Students review texts, illustrations, and lectures and decide which portions are critical and important. They make these decisions based on criteria from the teacher, authors, or other students. The students then paraphrase the idea and write it into their notes. Adding the kinesthetic exercise of writing furthers retention.

- **Predicting.** After studying a section of content, the students predict the material to follow or what questions the teacher might ask about that content. Prediction keeps students focused on the new content, adds interest, and helps them apply prior learnings to new situations, thus aiding retention.

- **Questioning.** After studying content, students generate questions about the content. To be effective, the questions should range from lower-level thinking of recall, comprehension, and application to higher-level thinking of analysis, synthesis, and evaluation (see Bloom's Taxonomy in Chapter 6). When designing questions of varying complexity, students engage in deeper cognitive processing, clarify concepts, and predict meaning and associations—all contributors to retention.

- **Summarizing.** Students reflect on and summarize in their heads the important material or skills learned in the lesson. This is often the last and critical stage where students can attach sense and meaning to the new learning. Summarizing rehearsal is also called closure (see the **Practitioner's Corner** on *closure* on p. 28 for further explanation).

Note on Constructivism. Those familiar with constructivism will recognize that the above strategies are consistent with the practices associated with that theory of learning.

PRACTITIONER'S CORNER

Using Rehearsal To Enhance Retention – Continued
General Guidelines

If the retention of new information or skill beyond the immediate lesson is an important expectation, then rehearsal must be a crucial part of the learner's processing. The considerations below should be incorporated into decisions about using rehearsal.

- **Teach** students rehearsal activities and strategies. As soon as they recognize the differences between rote and elaborative rehearsal, they can understand the importance of selecting the appropriate type for each learning objective. With practice, they should quickly realize that fact and data acquisition require rote rehearsal, while analysis and evaluation of concepts require elaborative rehearsal.

- **Remind** students to continuously practice rehearsal strategies until they become regular parts of their study and learning habits.

- **Keep** rehearsal relevant. Effective elaborative rehearsal relies more on making personally meaningful associations to prior learning than on time-consuming efforts that lack these student-centered connections. Associations that center in the teacher's experiences may not be relevant to students.

- **Remember** that time alone is not a trustworthy indicator of the extent of rehearsal. The degree of meaning associated with the new learning is much more significant than the time allotted.

- **Have** learners verbalize their rehearsal to peers or teachers while they are learning new material as this increases the likelihood of retention.

- **Provide** more visual and contextual clues to make rehearsal meaningful and successful for some students. Those with limited verbal competence will focus on visual and concrete lesson components to assist in their rehearsal. This will be particularly true of students whose native language is not English.

PRACTITIONER'S CORNER

Using the Primacy-Recency Effect in the Classroom

The primacy-recency effect describes the phenomenon whereby, during a learning episode, we tend to remember best that which comes first (prime-time-1), we remember second best that which comes last (prime-time-2), and we remember least that which comes just past the middle (down-time). This effect can lead to lessons that are more likely to be remembered when the teacher considers the following:

- **Teach the new material first** (after getting the students' focus) during prime-time-1. This is the time of greatest retention.
- **Avoid** asking students at the beginning of the lesson if they know anything about the topic being introduced. Since this is the time of greatest retention, almost anything that is said, including *incorrect* information, is likely to be remembered. Give the information and examples yourself to ensure they are correct.
- **Avoid** using precious prime-time periods for classroom management tasks, such as collecting absence notes or taking attendance. Do these before you get focus or during the down-time.
- **Use the down-time** portion to have students practice the new learning or to discuss it by relating it to past learnings.
- **Do closure** during prime-time-2. This is the learner's last opportunity to attach sense and meaning to the new learning, to make decisions about it, and to determine where and how it will be transferred to long-term storage.
- **Try to package lesson objectives** (or sub-learnings) in teaching episodes of about 20 minutes. Link the sublearnings according to the total time period available, e.g., two 20-minute lessons for a 40-minute teaching period, three for an hour period, and so on.

PRACTITIONER'S CORNER

Using Practice Effectively

Practice does not make perfect. It makes *permanent.* The purpose of practice is to allow the learner to use the newly-learned skill in a new situation with sufficient accuracy so that it will be correctly remembered and stored. Before allowing the students to begin practice, the teacher should model the thinking process involved and guide the class through each step of the new learning's application. Since practice makes permanent, the teacher should monitor the students' early practice to ensure that it is accurate and to provide timely feedback and correction if it is not. This guided practice helps eliminate initial errors and alerts the students to the critical steps in applying the new skill. Here are some considerations suggested by Hunter (1982) when guiding initial practice:

- **Amount of Material To Practice.** Practice should be limited to the smallest amount of material or skill that has the most meaning for the students. This allows for sense and meaning to be consolidated as the learner uses the new learning.

- **Amount of Time To Practice.** Practice should take place in short, intense periods of time when the student's working memory is running on prime time. When the practice period is short, students are more likely to be intent on learning what they are practicing.

- **Frequency of Practice.** New learning should be practiced frequently at first so that it is quickly consolidated into long-term storage. This is called *massed practice.* If we expect students to retain the information in active storage and to remember how to use it accurately, it should continue to be practiced over longer time intervals. This is called *distributed practice* and is the real key to accurate retention and application of information and skills over time.

- **Accuracy of Practice.** As students move through guided practice, it is important for the teacher to give prompt and specific feedback as to whether the practice is correct or incorrect and why. This process also gives the teacher valuable information about the degree of student understanding and whether it makes sense to move on or reteach portions that may be difficult for some students.

PRACTITIONER'S CORNER

Relearning Through Recall

Every time we recall information from long-term storage into working memory, we relearn it. Therefore, teachers should use classroom strategies that encourage students to recall previously-learned information regularly so they will relearn it. One strategy for doing this is to maintain learner participation throughout the lesson. Hunter (1982) calls this *active participation.* This principle of learning attempts to keep the mind of the student consistently focused on what is being learned or recalled through covert and overt activities.

The covert activity involves the teacher asking the students to recall previously learned information and to process it in some way. It could be, "Think of the conditions that existed in America just after the Civil War that we learned yesterday, and be prepared to discuss them in a few minutes." This statement informs the students that they will be held accountable for their recall. This accountability increases the likelihood that the students will recall the desired item and, thus, relearn it. It also alleviates the need for the teacher to call on every student to determine if the recall occurred. After sufficient wait time (see the **Practitioner's Corner** on the next page), overt activities are used to determine the quality of the covert recall.

Some suggestions on how to use active participation strategies effectively:

- **State the question** and allow thinking time *before* calling on a student for response. This holds all students accountable for recalling the answer until you pick your first respondent.

- **Give clear and specific directions** as to what the students should recall. Focus on the lesson objectives and not on the activities unless they were a crucial part of the learning. Repeat the question using different words and phraseology. This increases the number of cues that the learners have during their retrieval search.

- **Avoid predictable patterns** when calling on students, such as alphabetical order, up and down rows, or raised hands. These patterns signal the students *when* they will be held accountable, thereby allowing them to go off task before and after their turns.

PRACTITIONER'S CORNER

Using Wait Time To Increase Student Participation

Wait time refers to the period of teacher silence that follows the posing of a question before the first student is called on for a response. Regrettably, studies such as those conducted by Mary Budd Rowe (1974, 1978) of the University of Florida in Gainesville indicate that high school teachers had an average wait time of just over one second. Elementary teachers waited an average of three seconds. This was hardly enough time for slower retrievers, many of whom may know the correct answer, to locate that answer in long-term storage and retrieve it into working memory. Remember that as soon as the teacher calls on the first student, the remaining students **stop the retrieval process** and lose the opportunity to **re-learn** the information.

Rowe found that when teachers extended the wait time to at least **five** seconds or more:

- The length and quality of student responses increased
- There was greater participation by slower learners
- Students used more evidence to support inferences
- There were more higher-order responses.

These results occurred at all grade levels and in all subjects.

Rowe also noted positive changes in the behavior of teachers who consistently used wait time. Specifically, she observed these teachers:

- Used more higher-order questioning
- Demonstrated greater flexibility in evaluating responses
- Improved their expectations for the performance of slower learners.

There are many ways that teachers can use wait time in their classes. One effective method is called Think-Pair-Share, and is frequently used in cooperative learning groups. In this strategy, the teacher asks the students to think about a question. After adequate wait time, the students form pairs and exchange the results of their thinking. This is followed by asking some students to share their ideas with the entire class.

PRACTITIONER'S CORNER

Using Chunking To Enhance Retention

Chunking is the process whereby the brain perceives several items of information as a single item. Words are common examples of chunks. *Elephant* is composed of eight letters, but the brain perceives them as one item of information. The more items we can put into a chunk, the more information we can process in working memory and remember at one time. Chunking is a learned skill and, thus, can also be taught.

Pattern Chunking: This is most easily accomplished whenever we can find patterns in the material to be retained.

- Say we wanted to remember the number 3421941621776. Without a pattern, these 13 digits are treated as separate items and exceed working memory's functional capacity of about seven items. But we could arrange the numbers in groups that have meaning. For example, 342 (my house number), 1941 (when World War II began), 62 (my father's age), and 1776 (the Declaration of Independence). Now the number is only four chunks with meaning: 342 1941 62 1776.

- This example, admittedly contrived, shows how chunking can work at different levels. The task is to memorize the following string of words:

  COW GRASS FIELD TENNIS NET SODA DOG LAKE FISH

  We need a method to remember the sequence, since nine is more than the functional capacity of seven. We can chunk the sequence of items by using a simple story. First we see a **cow** eating **grass** in a **field**. Also in the field are two people playing **tennis**. One player hits the ball way over the **net**. They are drinking **soda** while their **dog** runs after the ball that went into the **lake**. The dog's splashing frightens the **fish**.

- Learning a step-by-step procedure for tying a shoelace or copying a computer file from a floppy to a hard disk are examples of pattern chunking. We group the items in a sequence and rehearse it mentally until it becomes one or a few chunks. Practicing the procedure further enhances the formation of chunks.

These examples show how information can be chunked in patterns. Learners can be shown other patterns and should select those that work best for them.

PRACTITIONER'S CORNER

Using Chunking To Enhance Retention – Continued

Categorical Chunking: This is a more sophisticated chunking process in that the learner establishes various types of categories to help classify large amounts of information. The learner reviews the information looking for criteria that will group complex material into simpler categories or arrays. The different types of categories can include:

- **Advantages and Disadvantages**. The information is categorized according to the pros and cons of the concept. Examples include energy use, abortion, and capital punishment.
- **Similarities and Differences**. The learner compares two or more concepts using attributes that make them similar and different. Examples are comparing the Articles of Confederation to the Bill of Rights, mitosis to meiosis, and the U.S. Civil War to the Vietnam War.
- **Structure and Function**. These categories are helpful with concepts that have parts with different functions, such as identifying the parts of an animal cell, a carburetor, or the human digestive system.
- **Taxonomies**. This system sorts information into hierarchical levels according to certain common characteristics. Examples are biological taxonomies (kingdom, phylum, class, etc.), taxonomies of learning (cognitive, affective, and psychomotor), and governmental bureaucracies.
- **Arrays**. These are less ordered than taxonomies in that the criteria for establishing the array are not always logical, but are more likely based on observable features. Human beings are classified, for example, by learning style and personality type. Dogs can be grouped by size, shape, or fur length. Clothing can be divided by material, season, and gender.

Making categorical chunking a regular part of classroom instruction can raise student learning, thinking, and retention significantly.

PRACTITIONER'S CORNER

Using Mnemonics To Help Retention

Mnemonics (from the Greek "to remember") are very useful devices for remembering unrelated information, patterns, or rules. They were developed by the ancient Greeks to help them remember dialogue in plays and for passing information to others when writing was impractical. There are many types of mnemonic schemes. Here are two that can be easily used in the classroom. Work with students to develop schemes appropriate for the content.

- **Rhyming Mnemonics.** Rhymes are simple and effective ways to remember rules and patterns. They work because if you forget part of the rhyme or get part of it wrong, the words lose their rhyme or rhythm and signal the error. To retrieve the missing or incorrect part you start the rhyme over again, and this helps you to relearn it. Have you ever tried to remember the fifth line of a song or poem without starting at the beginning? It is very difficult to do since each line serves as the auditory cue for the next line.

  Common examples of rhymes we have learned are "*I* before *e*, except after *c* ...," "Thirty days hath September ...," and "Columbus sailed the ocean blue ..."

  Here are rhymes that can help students learn information in other areas:

  The Spanish Armada met its fate
  In fifteen hundred and eighty-eight.

  Divorced, beheaded, died;
  Divorced, beheaded, survived.
  (The fate of Henry VIII's six wives, in chronological order.)

  The number you are dividing by,
  Turn upside down and multiply.
  (Rule for dividing by fractions.)

  This may seem like a clumsy system, but it works. Make up your own rhyme, alone or with the class, to help you and your students remember information.

PRACTITIONER'S CORNER

Using Mnemonics To Help Retention – Continued

- **Reduction Mnemonics**: In this scheme, you reduce a large body of information to a shorter form and use a letter to represent each shortened piece. The letters are either combined to form a real or artificial word or are used to construct a simple sentence. For example, the real word **HOMES** can help us remember the names of the great lakes (Huron, Ontario, Michigan, Erie, and Superior). The name **ROY G BIV** aids in remembering the seven colors of the spectrum (red, orange, yellow, green, blue, indigo, and violet). The artificial word **NATO** recalls **N**orth **A**tlantic **T**reaty **O**rganization. The sentence **My Very Earnest Mother Just Served Us Nine Pizzas** can help us remember the nine planets of the solar system in order from the sun (Mercury, Venus, Earth, Mars, Jupiter, Uranus, Neptune, and Pluto). Here are other examples:

  Please Excuse My Dear Aunt Sally
  (The order for solving algebraic equations: Parenthesis, Exponents, Multiplication, Division, Addition, Subtraction.)

  Frederick Charles Goes Down And Ends Battle
  (F, C, G, D, A, E, B. The order that sharps are entered in key signatures; reverse the order for flats.)

  McHALES
  (The different forms of energy: Mechanical, Chemical, Heat, Atomic, Light, Electrical, and Solar.)

  In Poland, Men Are Tall
  (The stages of cell division in mitosis: Interphase, Prophase, Metaphase, Anaphase, and Telophase.)

  Krakatoa Positively Casts Off Fumes, Generally Sulfurous Vapors
  (The descending order of zoological classifications: Kingdom, Phylum, Class, Order, Family, Genus, Species, Variety.)

  King Henry Doesn't Mind Drinking Cold Milk
  (The descending order of metric prefixes: Kilo, Hecto, Deca, (measure), Deci, Centi, and Milli.)