CHAPTER 2

How the Brain Processes Information

There are probably more differences in human brains than in any other animal partly because the human brain does most of its developing in the outside world.

—Robert Ornstein and Richard Thompson
The Amazing Brain

CHAPTER HIGHLIGHTS

This chapter presents a modern dynamic model of how the brain deals with information from the senses. It covers the behavior of the two temporary memories, the criteria for long-term storage, and the impact of the self-concept on learning.

Although the brain remains largely a mystery beyond its own understanding, we are slowly uncovering more about its baffling processes. Using scanning technologies, researchers can display in vivid color the differences in brain cell metabolism that occur in response to different types of brain work. A computer constructs a color-coded map indicating what different areas are doing during such activities as learning new words, analyzing tones, doing mathematical calculations, or responding to images. One thing is clear: The brain calls selected areas into play, depending on what the individual is doing at the moment. This knowledge encourages us to construct models that explain data and behavior, but models are useful only when they contain some predictability about specific operations. In choosing a model, it is necessary to select those specific operations that can be meaningfully depicted and represented in a way that is consistent with more recent research findings.

The Information Processing Model

Numerous models exist to explain brain behavior. An internet search for "information processing model" results in hundreds of examples. Nonetheless, despite their variations in color and design, most of them make use of the same research findings and include the same basic components of memory and information flow. In designing a model for this book, I needed one that would accurately represent the complex research of neuroscientists in such a way as to be understood by educational practitioners. I recognize that a model is just one person's view of reality, and I readily admit that this particular information processing model comes closest to *my* view of how the brain learns. It differs from some other models in that it escapes the limits of the computer metaphor and recognizes that learning, storing, and remembering are dynamic and interactive processes. Beyond that, the model incorporates much of the recent findings of research and is sufficiently flexible to adjust to new findings as they are revealed. I have already made several changes in this model since I began working with it more than 30 years ago. My hope is that classroom teachers will be encouraged to reflect on their methodology and decide if there are new insights here that could affect their instruction and improve learning.

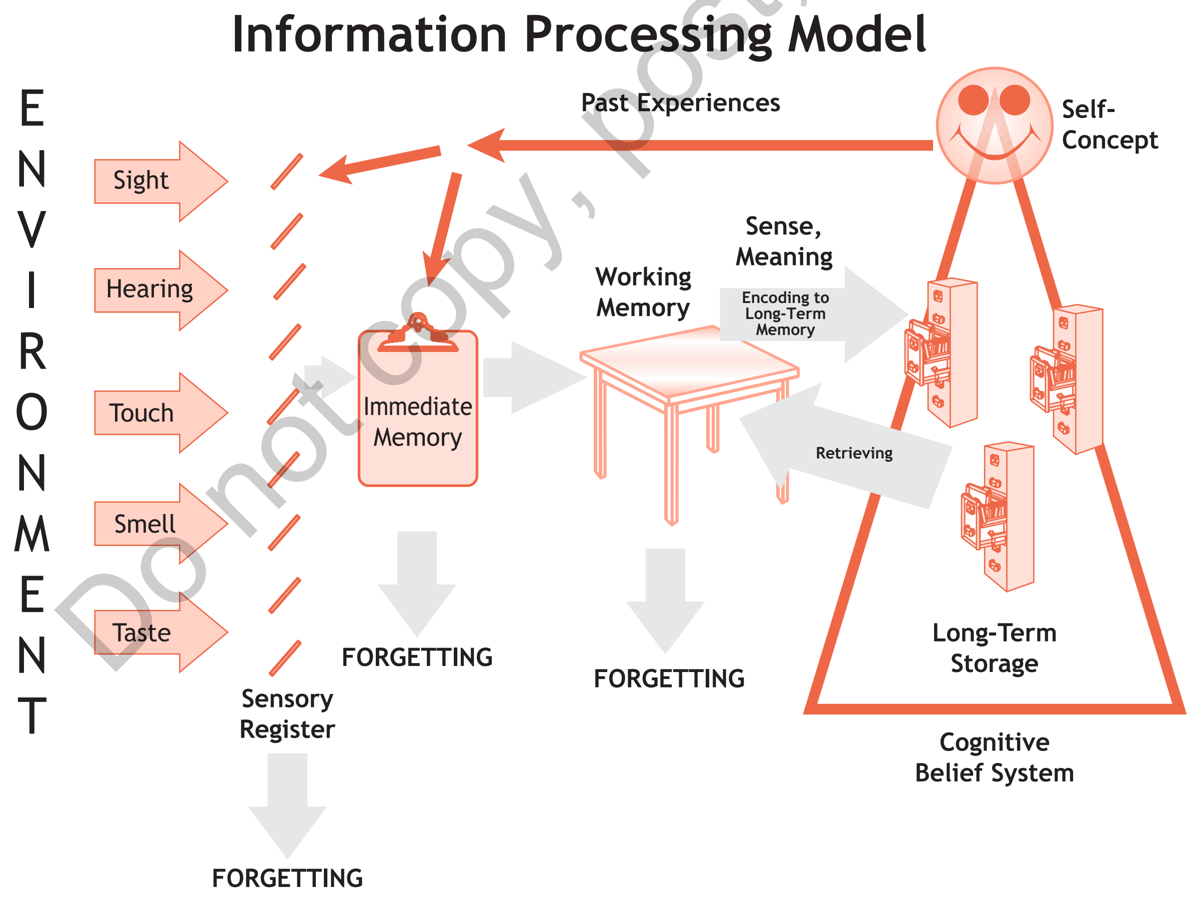
ORIGINS OF THE MODEL

The precursor of this model was developed by Robert Stahl (1985) of Arizona State University in the early 1980s. Stahl's more complex model synthesized the research from the 1960s and 1970s on cognitive processing and learning. His goal was to convince teacher educators that they should use his model to help prospective teachers understand how and why learning occurs. He also used the model to develop an elaborate and fascinating learning taxonomy designed to promote higher-order thinking skills. Certain components of the model needed to be altered as a result of subsequent discoveries in neuroscience.

USEFULNESS OF THE MODEL

The model discussed here (Figure 2.1) has been updated over the years so that it can be useful to the widest range of teacher educators and practitioners. It uses common objects to represent various stages in the process. Even this revised model does not pretend to include

FIGURE 2.1 The information processing model shown here represents a simplified explanation of how the brain deals with information from the environment. Information from the senses passes through the sensory register to immediate memory and then on to working memory for conscious processing. If the learner attaches sense and meaning to the learning, it is likely to be stored. The self-concept often determines how much attention the learner will give to new information.



all the ways that researchers believe the human brain deals with information, thought, and behavior. It limits its scope to the major cerebral operations that deal with the collecting, evaluating, storing, and retrieving of information—the parts most useful to educators.

The model starts with information from our environment and shows how the senses reject or accept it for further processing. It then explains the two temporary memories, how they operate, and the factors that determine if a learning is likely to be stored. Finally, it shows the inescapable impact that experiences and self-concept have on present and future learning. The model is simple, but the processes are extraordinarily complex. Knowing how the human brain seems to process information and learn can help teachers plan lessons that students are more likely to understand and remember.

LIMITATIONS OF THE MODEL

Although the explanation of the model will follow items going through the processing system, it is important to note that this linear approach is used solely for simplicity and clarity. Much of the recent evidence on memory supports a model of parallel processing—that is, many items are processed quickly and simultaneously (within limits), taking different paths through and out of the system. Memories are dynamic and dispersed, and the brain has the capacity to change its own properties as the result of experience. Even though the model may seem to represent learning and remembering as a mechanistic process, it must be remembered that we are describing a *biological process*. Nonetheless, I have avoided a detailed discussion of the biochemical changes that occur within and between neurons. That would not contribute to the understanding necessary to convert the fruits of research and this model into successful classroom practice, which is, after all, our goal.

The brain changes its own properties as a result of experience.

INADEQUACY OF THE COMPUTER MODEL

The rapid proliferation of computers has encouraged the use of the computer model to explain brain functions. This is indeed tempting, especially as computers become more complex and more integrated into various components of society. Using the analogy of input, processing, and output seems so natural, but there are serious problems with such a model. Certainly, the smallest handheld calculator can out-tally the human brain in solving complex mathematical operations. More powerful computers can play chess, translate one language into another, and correct massive manuscripts for most spelling and grammatical errors in just seconds. The brain performs more slowly because of the time it takes for a nerve impulse to travel along the axon, because of synaptic delays, and because the capacity of its working memory is limited. But computers cannot exercise judgment with the ease of the human brain. Even the most sophisticated computers are closed linear systems limited to binary code, the zeros and ones in linear sequences that are the language of computer operations.

The human brain has no such limitations. It is an open, parallel-processing system continually interacting with the physical and social worlds outside. It analyzes, integrates, and synthesizes information and abstracts generalities from it. Each neuron is alive and altered by its experiences and its environment. As you read these words, neurons are interacting with each other, reforming and dissolving storage sites, and establishing different electrical patterns that correspond to your new learning. Rereading these words will strengthen the neural connections that make those patterns and increase the depth of your learning.

How the brain stores information is also very different from a computer. The brain stores sequences of patterns, and recalling just one piece of a pattern can activate the whole. We can also identify the same thing in different forms, such as recognizing our best friend from behind or by her walk or voice. Computers cannot yet deal well with such variations. Moreover, emotions play an important role in human processing, comprehension, and creativity. And the ideas generated by the human brain often come from images, not from logical propositions. For these and many other reasons, the computer model is at this time, in my opinion, inadequate and misleading. Of course, it is possible that sometime in the not-too-distant future, computers using artificial intelligence will be able to mimic some of the qualities, capabilities, and weaknesses possessed by the human brain.

As you read these words, neurons in your brain are interacting with each other in patterns that correspond to your new learning.

At first glance, the model may seem to perpetuate the traditional approach to teaching and learning—that students repeat newly learned information in quizzes, tests, and reports. On the contrary, the new research is revealing that students are more likely to gain greater understanding of and derive greater pleasure from learning when allowed to *transform* the learning into creative thoughts and products. This model emphasizes the power of transfer during learning and the importance of moving students through higher levels of complexity of thought. This will be explained further in Chapters 4 and 8.

The Senses

Our brain takes in more information from our environment in a single day than the largest computer does in a year. That information is detected by our five major senses. (*Note*: Apart from the five classical senses of sight, hearing, smell, touch, and taste, our body has special sensory receptors that detect internal signals. For example, we have receptors inside the ear and body muscles that detect the body's movement and position in space; sensory hairs in the ear that detect balance and gravity; stretch receptors in muscles that help the brain coordinate muscular contraction; and pain receptors throughout the body. For the purposes of the model, however, I have focused on the traditional five senses because they are the major receptors of *external* stimuli used by the brain to acquire information and skills.)

All sensory stimuli enter the brain as a stream of electrical impulses that result from neurons firing in sequence along the specific sensory pathways. The brain sits in a black box (the skull) and does not see light waves or hear sound waves. Rather, certain specialized modules of neurons process the electrical impulses created by the light and sound waves into what the brain *perceives* as vision and sound.

The senses do not all contribute equally to our learning. Over the course of our lives, sight, hearing, and touch (including kinesthetic experiences) contribute the most. Our senses constantly collect tens of thousands of bits of information from the environment every second, even while we sleep. That number may seem very high, but think about it. The nerve endings on your skin are detecting the clothes you are wearing. Your ears pick up sounds around you, the rods and cones in your eyes are reacting to this print as they move across the page, you may still be tasting recent food or drink, and your nose may be detecting an odor. Put these data together and you see how they can add up. Of course, the stimuli must be strong enough for the senses to detect and record them.

Sensory Register

Imagine if the brain had to give its full attention to all those bits of data at once. We would blow the cerebral equivalent of a fuse! Fortunately, the brain has evolved a system for quickly screening all these data to determine their importance to the individual. This system involves the *thalamus* (located in the limbic system) and a portion of the brain stem known as the *reticular activating system* (RAS). This system, which is also referred to as the *sensory register*, is drawn in the model as the side view of Venetian blind slats (see the slashes in Figure 2.1). Like the blinds, the sensory register filters incoming information to determine how important it is.

All incoming sensory information (except smell, which goes directly to the amygdala and other destinations) is sent first to the thalamus, which briefly monitors the strength and nature of the sensory impulses for survival content and, in just milliseconds (a millisecond is one one-thousandth of a second), uses the individual's past experiences to determine the data's degree of importance. Most of the data signals are unimportant, so the sensory register allows them to drop out of the processing system. Have you ever noticed how you can be in a room studying while there is construction noise outside? Eventually, it seems that you no longer hear the noise. Your sensory register is blocking these repetitive stimuli, allowing your conscious brain to focus on more important things. This process is called *perceptual* or *sensory filtering*, and, to a large degree, we are unaware of it.

The sensory register does hold sensory information for a very brief time (usually less than a second). This is referred to as **sensory memory**. Let's say you are intently watching a football game during the final minutes of play. Your spouse comes in and starts talking about an important matter. After a few minutes, your spouse says, "You're not listening to me!" Without batting an eye you say, "Yes, I am," and then proceed to repeat your spouse's last sentence word for word. Fortunately, you captured this sensory memory trace just before it decayed, and you nipped a potential argument in the bud.

Short-Term Memory

As researchers gain greater insight into the brain's memory processes, they have had to devise and revise terms that describe the various stages of memory. *Short-term memory* is used by cognitive neuroscientists to include all of the early steps of temporary memory that will lead to stable long-term memory. Short-term memory is related to **immediate memory** and **working memory**. A conventional distinction describes short-term memory as the storage of information for a limited time, while working memory is a theoretical framework referring to the structures and conscious processes used for manipulating information (Chai et al., 2018).

IMMEDIATE MEMORY

Sensory data that are not lost move from the thalamus to the sensory processing areas of the cortex and through the first of two temporary memories, called *immediate memory*. The idea that we seem to have two temporary memories is a way of explaining how the brain deals with large amounts of sensory data and how we can continue to process these stimuli subconsciously for many seconds beyond the sensory register's time limits. Indeed, some neuroscientists equate sensory memory and immediate memory, arguing that separating them is more a convenience than a biological reality.

You cannot recall information that your brain does not retain.

For our purposes, we will represent immediate memory in the model as a clipboard—a place where we put information briefly until we make a decision on how to dispose of it. Immediate memory operates subconsciously or consciously and holds data for up to about 30 seconds. (*Note*: The numbers used in this chapter are averages over time. There are always exceptions to these values as a result of human variations or pathologies.) The individual's experiences determine its importance. If the item is of little or no importance within this time frame, it drops out of the processing system. For example, if you ask a friend for the telephone number of the local pizza parlor, you usually can remember it just long enough to make the call. After that, the number is of no further importance and drops out of immediate memory. Later on, you will have little success in remembering the entire number because you cannot recall information that your brain does not retain.

Examples of Immediate Memory at Work

Here are two other examples to understand how the processing occurs up to this point. Suppose you decide to wear a new pair of shoes to work today. They are snug, so when you put them on, the receptors in your skin send pain impulses to the sensory register. For a short time, you feel discomfort. After a while, however, as you get involved with work, you do not notice the discomfort signals anymore. The sensory register is now blocking the impulses from reaching your consciousness. Should you move your foot in a way that causes the shoe to pinch, however, the sensory register will pass this pain stimulus along to your consciousness, and you will become aware of it once again.

Another example: You are sitting in a classroom, and a police car with its siren wailing passes by. Experience reminds you that a siren is an important sound. Signals from the sensory register pass the auditory stimuli over to immediate memory. If over the next few seconds the sound of the siren gets fainter, experience signals the immediate memory that the sound is of no further importance, and the auditory data are blocked and dropped from the system. All this is happening subconsciously while your attention is focused on something else. If asked about the sound 15 minutes later, you will not remember it. You cannot recall what you have not stored.

Suppose, on the other hand, that the siren sound gets louder and suddenly stops, followed by another siren that gets louder and stops. Experience will now signal that the sounds are important because they are nearby, may affect your survival, and therefore require your attention. At this point, the now-important auditory data move rapidly into working memory for conscious processing so that you can decide what action to take.

Threats and Emotions Affect Memory Processing

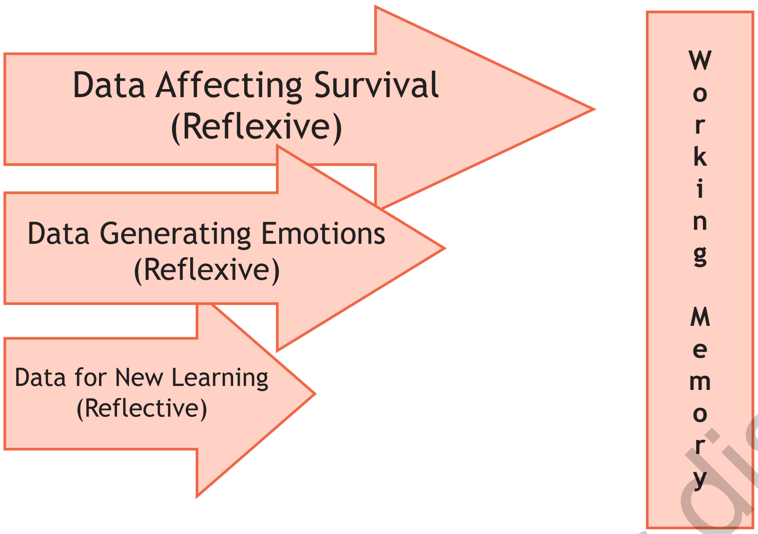
This last example illustrates another characteristic of brain processing: There is a hierarchy of response to sensory input (see Figure 2.2). Any input that is of higher priority diminishes the processing of data of lower priority. The brain's main job is to help its owner survive. Thus, it will process immediately any data that past experience interprets as posing a threat to the survival of the individual, such as a burning odor, a snarling dog, or someone threatening bodily injury. Upon receiving the stimulus, the reticular activating system (RAS) sends a rush of adrenaline throughout the brain. This is a reflexive response that shuts down all unnecessary activity and directs the brain's attention to the source of the stimulus.

Emotional data also take high priority. When an individual responds emotionally to a situation, the older limbic system (stimulated by the amygdala) takes a major role, and the complex cognitive processes are suspended. We have all had experiences when anger, fear of the unknown, or joy quickly overcame our rational thoughts. This reflexive override of conscious thought can be strong enough to cause temporary inability to talk ("I was dumbfounded") or move ("I froze"). This happens because the hippocampus is susceptible to stress hormones that can inhibit cognitive functioning and long-term memory.

Under certain conditions, emotions can enhance memory by causing the release of hormones that stimulate the amygdala to signal brain regions to strengthen memory. Strong emotions can shut down conscious processing during the event while enhancing our memory of it. Emotion is a powerful and misunderstood force in learning and memory. Another way of stating the hierarchy illustrated in Figure 2.2 is that before students will turn their attention to cognitive learning (the curriculum), they must feel physically safe and emotionally secure in the school environment.

Over the years, most teacher preparation classes have told prospective teachers to focus on reason, cover the curriculum, and avoid emotions in their lessons. Now we need to enlighten educators about how emotions consistently affect attention and learning. Districts must

FIGURE 2.2 **Data affecting survival and data generating emotions are processed ahead of data for new learning, which in school is called curriculum.**



ensure that schools are free of bullying, weapons, and violence. Teachers can then promote emotional security in the classroom by establishing a positive climate that encourages students to take appropriate risks. Students must sense that the teacher *wants* to help them be right rather than catch them being wrong.

Moreover, school superintendents and board members need to examine their actions, which set the emotional climate of a district. Is it a place where people want to come to work? Does the district reward or frown on appropriate risk-taking?

How a person "feels" about a teaching or learning situation determines the amount of attention devoted to it. Emotions interact with reason to support or inhibit learning. To be successful learners and productive citizens, we need to know how to use our emotions intelligently. Thus, we need to explore what and how we teach students about their emotions. For example, we could teach about controlling impulses, delaying gratification, expressing feelings, managing relationships, and reducing stress. Students should recognize that they can manage their emotions for greater productivity and can develop emotional skills for greater success in life.

Students must feel physically safe and emotionally secure before they can focus on the curriculum.

How a person "feels" about a learning situation determines the amount of attention devoted to it.

WORKING MEMORY

Working memory is also a temporary memory and the place where conscious, rather than subconscious, processing occurs. The information processing model represents working memory as a work table, a place of limited capacity where we can build, take apart, or rework ideas for eventual storage somewhere else. When something is in working memory, it generally captures our focus and demands our attention. Information in working memory can come from the sensory/immediate memories or be retrieved from long-term memory. Brain imaging studies show that most of working memory's activity occurs in the frontal lobes, although other parts of the brain are often called into action (e.g., Funahashi, 2017).

Capacity of Working Memory

Psychologist George Miller (1956) discovered years ago that working memory can handle only a few items at once. Not surprisingly, this functional capacity changes with age, in that children have a smaller capacity than adolescents and adults (Cowan et al., 2010; Gilchrist et al., 2009; Zhang et al., 2016). Preschool infants can deal with about two items of information at once. Preadolescents can handle three or more. Through adolescence, further cognitive expansion occurs, and the capacity increases to five or more.

More recent research has raised questions about the exact capacity limit of working memory. Some studies suggest that it now may be three to five chunks for adults. Others say it is difficult to state an actual number because variables such as interest, mental time delays, and distractions may undermine and invalidate experimental attempts to find a reliable capacity limit (Cowan, 2010). Nonetheless, most of the research evidence to date supports the notion that working memory has a functional limit and that the actual number varies with the learner's age and the type of input (factual information, visual, spatial, etc.; Brady et al., 2016; Myers et al., 2014).

We can test this notion of limited capacity. Get a pencil and a piece of paper. When ready, stare at the following number for five seconds, then look away and write it down. Ready? Go.

92170

Check the number you wrote down. Chances are you got it right. Let us try it again with the same rules. Stare at the next number for five seconds, then look away and write it down. Ready? Go.

4915082637

Again, check the number you wrote down. Did you get all 10 of the digits in the correct sequence? Probably not. Because the digits were random, you had to treat each digit as a single item, and your working memory just ran out of functional capacity.

This limited capacity explains why we have to memorize a song or a poem in stages. We start with the first group of lines by repeating them frequently (a process called **rehearsal**). Then we memorize the next lines and repeat them with the first group, and so on. It is possible to increase the number of items within the functional capacity of working memory through a process called *chunking*. This process will be explained more fully in the next chapter.

Why would such a sophisticated structure like the human brain exhibit such severe limitations in working memory capacity? No one knows for sure. One possible explanation is that it is unlikely during the development of the brain thousands of years ago that our ancestors had to process or identify more than one thing at a time. It is also unlikely that they had to make several split-second decisions simultaneously. Even in fight-or-flight situations, there probably was only one enemy or predator. In today's technology-laden environment, however, people are often trying to do several things at once during their workday, making the memory's capacity limits more obvious.

We should not look upon these capacity limitations necessarily as a weakness. Having a relatively small number of items in working memory may allow the items to become more easily associated with each other—that is, chunked—without causing confusion. From one point of view, this could be a distinct cognitive advantage, especially for children. We should also note that, although we have several items in working memory simultaneously, we can really focus on only *one* item at a time (Oberauer & Bialkova, 2009).

IMPLICATIONS FOR TEACHING

Can you see the implication this functional capacity has on lesson planning? It means that the elementary teacher who expects students to remember in one lesson the eight rules for using the comma is already in trouble. So is the high school or college teacher who wants students to learn in one lesson the names and locations of the 10 most important rivers in the world. Keeping the number of items in a lesson objective within the age-appropriate capacity limit increases the likelihood that students will remember more of what they learned. In this setting, less is more!

Time Limits of Working Memory

Working memory is temporary and can deal with items for only a limited time. How long is that time? This intriguing question has been clinically investigated for over a century, starting with the work of Hermann Ebbinghaus (1850–1909) during the 1880s. He concluded that we can process items intently in working memory (he called it short-term memory) for up to 45 minutes before becoming fatigued. Because Ebbinghaus mainly used himself as the subject to measure retention in laboratory conditions, the results are not readily transferable to the average high school classroom.

Any discussion of time limits for processing new information has to include motivation. People who are intensely motivated about a subject can spend hours reading and processing it. They are not likely to quit until they are physically tired. That is because motivation is essentially an emotional response, and we already know that emotions play an important part in attention and learning. Students are not equally motivated in all subjects. Therefore, these time limits are more likely to apply to students who are in learning episodes that they do not find motivating.

Russell (1979) shows this time span to be much shorter and age dependent. More recent studies of the novelty-seeking brain of today are very similar (Baddeley, 2018). The time span is, for preadolescents, about 5 to 10 minutes, and for adolescents and adults, about 10 to 20 minutes. These are average times, and it is important to understand what the numbers mean. An adolescent (or adult) normally can process an item in working memory *intently* for 10 to 20 minutes before mental fatigue (as opposed to physical fatigue), interference from other items in working memory, or boredom with that item occurs and the individual's focus drifts. For focus to continue, there must be some change in the way the individual is dealing with the item. For example, the person may switch from thinking about it to physically using it or to making different connections to other learnings. If something else is not done with the item, it is likely to fade quickly from working memory.

This is not to say that some items cannot remain in working memory for hours, or perhaps days. Sometimes, we have an item that remains unresolved—a question whose answer we seek or a troublesome family or work decision that must be made. These items can remain in working memory, continually commanding some attention, and, if of sufficient importance, interfere with our accurate processing of other information. This is often referred to as *preoccupation*.

Keep the number of items in a lesson objective within the capacity limits of students and they are likely to remember more of what they learned. Less is more!

These time limits suggest that packaging lessons into 15- to 20-minute components is likely to result in maintaining greater student interest than one 40-minute lesson. It seems that, with many lessons, shorter is better! We will talk more about lesson length and memory in Chapter 3.

CRITERIA FOR LONG-TERM STORAGE

Now comes the most important decision of all: Should the items in working memory be encoded to long-term storage for future recall, or should they drop out of the system? This is an important decision because we cannot recall what we have not stored. Yet teachers teach with the hope that students will retain the learning objective for future use. So if the learner is ever to recall this information in the future, it has to be stored.

What criteria does the working memory use to make that decision? Figure 2.2 can help us here. Information that has survival value is quickly stored. You don't want to have to learn every day that walking in front of a moving bus or touching a hot stove can injure you. Strong emotional experiences also have a high likelihood of being permanently stored. We tend to remember the best and worst things that happened to us.

But in classrooms, where the survival and emotional elements should be minimal or absent, other factors come into play. It seems that the working memory connects with the learner's past experiences and asks just two questions to determine whether an item is saved or rejected: "Does this make *sense*?" and "Does this have *meaning*?" Imagine the many hours that go into planning and teaching lessons, and it all comes down to these two questions! Let us review them.

- **Does this make sense?** This question refers to whether the learner can understand the item on the basis of past experiences. Does it "fit" into what the learner knows about how the world works? When a student says, "I don't understand," it means the student is having a problem making sense of the learning.
- **Does this have meaning?** This question refers to whether the item is *relevant* to the learner. For what purpose should the learner remember it? Meaning, of course, is a very personal thing and is greatly influenced by that person's experiences. The same item can have great meaning for one student and none for another. Questions such as "Why do I have to know this?" or "When will I ever use this?" indicate that the student has not, for whatever reason, perceived this learning as relevant.

Here are two examples to explain the difference between sense and meaning. Suppose I tell a 15-year-old student that the minimum age for getting a driver's license in his state is age 16, but it is 17 in a neighboring state. He can understand this information, so it satisfies the sense criterion. But the age in his own state is much more relevant to him because this is where he will apply for his license. Chances are high that he will remember his own state's minimum age (it has both sense *and* meaning) but will forget that of the neighboring state (it has sense but lacks meaning).

Suppose you are a teacher and you read in the newspaper that the average salary for accountants last year was $80,000, whereas the average for teachers was $60,000. Both numbers make sense to you, but the average teacher's salary has more meaning because you are in that profession.

A learner will most likely store information if it makes sense and has meaning.

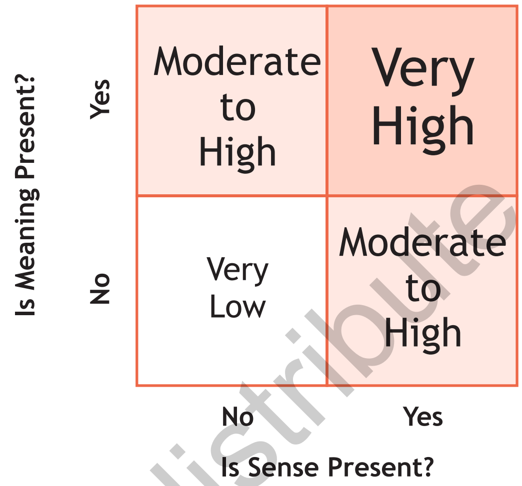
Whenever the learner's working memory perceives that an item does not make sense or have meaning, the probability of it being stored is extremely low (see Figure 2.3). If either sense or meaning is present, the probability of storage increases significantly (assuming, of course, no survival or emotional component). If both sense *and* meaning are present, the likelihood of long-term storage is very high.

Relationship of Sense to Meaning

Sense and meaning are independent of each other. Thus, it is possible to remember an item because it makes sense but has no meaning. If you have ever played *Trivial Pursuit* or similar games, you may have been surprised at some of the answers you knew. If another player asked how you knew that answer, you may have replied, "I don't know. It was just there!" This happens to all of us. During our lifetime, we pick up bits of information that make sense at the time and, although they are trivial and have no meaning, make their way into our long-term memory.

It is also possible to remember an item that makes no sense but has meaning. My sixth-grade teacher once asked our class to memorize Lewis Carroll's nonsense poem "Jabberwocky." It begins, *'Twas brillig, and the slithy toves did gyre and gimble in the wabe.* The poem made no sense to us sixth graders, but when the teacher said that she would call on each of us the next day to recite it before the class, it suddenly had great meaning. Because I didn't want to make a fool of myself in front of my peers, I memorized it and recited it correctly the next day, even though I had no idea what the sense of it was.

FIGURE 2.3 The probability of storing information varies with the degree of sense and meaning that are present.



Brain scans and other studies have shown that when new learning is readily comprehensible (sense) and can be connected to past experiences (meaning), there is substantially more cerebral activity followed by dramatically improved retention (Bein et al., 2014; Stern, 2015).

MEANING IS MORE SIGNIFICANT

Of the two criteria, meaning has the greater impact on the probability that information will be stored. Think of all the television programs you have watched that are *not* stored, even though you spent one or two hours with the program. The show's content or storyline made sense to you, but if meaning was absent, you just did not save it. It was *entertainment,* and no learning resulted from it. You might have remembered a summary of the show, or whether it was enjoyable or boring, but not the details. On the other hand, if the story reminded you of a personal experience, then meaning was present, and you were more likely to remember more details of the program.

Test Question No. 2: Learners who can perform a new learning task well are likely to retain it. True or false?

Answer: False. We cannot presume that because a learner performs a new learning task well it will be permanently stored. Sense and/or meaning must be present in some degree for storage to occur.

IMPLICATIONS FOR TEACHING

Now think of this process in the classroom. Every day, students listen to things that make sense but lack meaning. They may diligently follow the teacher's instructions to perform a task repeatedly and may even get the correct answers, but if they have not found meaning after the learning episode, there is little likelihood of long-term storage. Mathematics teachers are often frustrated by this. They see students using a certain formula to solve problems correctly one day, but they cannot remember how to do it the next day. If the process was not stored, the information is treated as brand new again!

Sometimes, when students ask why they need to know something, the teacher's response is "Because it's going to be on the test." This response adds little meaning to a learning, unless the student is highly motivated by test scores. Students resort to writing the learning in a notebook so that it is preserved in writing but not in memory. We wonder the next day why they forgot the lesson objective.

Teachers spend most of their planning time devising lessons so that students will *understand* the learning objective (i.e., make sense of it). But to convince a learner's brain to persist with that objective, teachers need to be more mindful of helping students establish *meaning*. We should remember that what was meaningful for *us* when we were children may not be necessarily meaningful for children today.

Past experiences always influence new learning. What we already know acts as a filter, helping us attend to those things that have meaning (i.e., relevance) and discard those that do not. If we expect students to find meaning, we need to be certain that today's curriculum contains connections to *their* past experiences, not just ours. Further, the enormous size and the strict separation of secondary curriculum areas do little to help students find the time to make relevant connections between and among subject areas. Helping students to make connections between subject areas by integrating the curriculum increases meaning and retention, especially when students recognize a future use for the new learning. Meaning is so powerful that most states prohibit trial lawyers from using what is dubbed the "golden rule" argument. It asks the jury, "If you were in this person's situation, what would you have done?"

Past experiences always influence new learning.

LONG-TERM STORAGE

Storing occurs when the hippocampus encodes information and sends it to one or more long-term storage areas. The encoding process takes time and usually occurs during deep sleep. While learners may *seem* to have acquired the new information or skill in a lesson, there is no guarantee that storage will be permanent after the lesson. How do we know if **retention** has occurred? If the student can accurately recall the learning after a specific period of time has passed, we say that the learning has been retained. Because research on retention shows that the greatest loss of newly acquired information or a skill occurs within the first 18 to 24 hours, the 24-hour period is a reasonable guideline for determining if information was transferred into long-term storage. If a learner cannot recall new learning after 24 hours, there is a high probability that it was not permanently stored and, thus, can never be recalled. This point has implications for how we test students for retention of previously learned material. See the Practitioner's Corner: Testing Whether Information Is in Long-Term Storage at the end of this chapter. Sometimes, we store only the gist of an experience, not the specifics. This may occur after watching a movie or television program. We store a generalization about the plot but few, if any, details.

Test Question No. 3: Reviewing material just before a test is a good practice to determine how much has been retained in long-term storage. True or false?

Answer: False. Reviewing material just before a test allows students to enter the material into working (temporary) memory for immediate use. Thus, the test cannot verify that what the learner recalled actually came from long-term storage.

The long-term storage areas are represented in Figure 2.1 as file cabinets—places where information is kept in some type of order. I have resisted the temptation to replace the file cabinets in the model with a more technologically current storage device, such as a computer hard drive or flash drive. As you may recall, I mentioned earlier the inadequacy of comparing brain functions to computer operations, and introducing such a storage device into the model would contradict that comparison.

Although there are three file cabinets in the diagram for simplicity, we do not know how many long-term storage sites actually are in the brain. Memories are not stored as a whole in one place. Different parts of a memory are stored in various sites that reassemble when the memory is recalled. Long-term memory is a dynamic, interactive system that activates storage areas distributed across the brain to retrieve and reconstruct memories.

Long-Term Memory and Long-Term Storage

This is a good place to explain the difference between *long-term memory* and *long-term storage,* as I use those terms in the model. Long-term memory refers to the process of storing and retrieving information, while long-term storage refers to the areas in the brain where the memories are kept.

THE COGNITIVE BELIEF SYSTEM

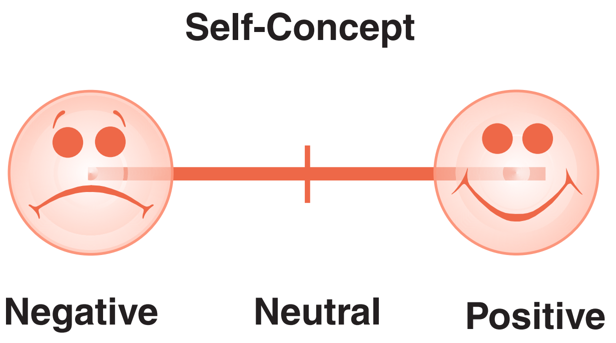
The total of all that is in our long-term storage areas forms the basis for our view of the world around us and how it works. This information helps us to make sense out of events, to understand the laws of nature, to recognize cause and effect, and to form decisions about abstract ideas such as goodness, truth, and beauty. This total construct of how we see the world is called the **cognitive belief system**. It is shown in the information processing model as a large triangle extending beyond the long-term storage areas (file cabinets). It is drawn this way to remind us that the thoughts and understandings that arise from the long-term storage data are greater than the sum of the individual items. In other words, one marvelous quality of the human brain is its ability to combine individual items in many different ways. As we accumulate more items, the number of possible combinations grows exponentially.

Because no two of us have the same data in our long-term storage (not even identical twins raised in the same environment have identical data sets), no two of us perceive the world in exactly the same way. People can put the same experiences together in many different ways. To be sure, there are areas of agreement: gravity, for example (few rational people would dispute its effects), or inertia, as most people have experienced the lurch forward or backward when a moving vehicle rapidly changes speed. There can be strong disagreement, however, about what makes an object or person beautiful or an act justified. The persistent debates over abortion and capital punishment are testimony to the wide range of perspectives that people have over any issue. These differences reflect the ways individuals use the experiences in their long-term storage areas to interpret the world around them.

Here is a simple example of how people's experiences can cause them to interpret the same information differently. Close your eyes and form the mental image of an "old bat." Go ahead, try it! What picture comes to mind? For some baseball fans, it might be a marred wooden club that has been in too many games. A zoologist, however, might picture an aging fruit bat as it flies haltingly among the trees in search of food. Still others might recall an old hag whose constant complaining made their lives unpleasant. Here are at least three very different images generated by the same two words, each one formed by individuals whose experiences are different from the others.

The cognitive belief system is our view of the world around us and how it works.

FIGURE 2.4 **Self-concept describes how we see ourselves in the world. It can range from very negative to very positive and can vary with different learning.**



SELF-CONCEPT

Deep within the cognitive belief system lies the **self-concept**. While the cognitive belief system portrays the way we see the world, the self-concept describes the way we view *ourselves* in that world. I might conceptualize myself as a good softball player, an above-average student, or a poor mathematician. These and a long list of other descriptions form part of a person's self-concept.

The self-concept is represented in the information processing model (Figure 2.1) as a face and is placed at the apex of the triangle to emphasize its importance. *Self-concept* is used here as a neutral term that can run the gamut from very positive to very negative (see Figure 2.4). The face on the diagram of the model has a smile, indicating a positive self-concept. But for some people, the face might have a frown because they may not see themselves as positive beings in their world. Emotions play an important role in forming a person's self-concept.

Self-Concept and Past Experiences

Our self-concept is shaped by our past experiences. Some of our experiences, such as passing a difficult test or getting recognition for a job well done, raised our self-concept. Other experiences, such as receiving a reprimand or failing to accomplish a task, lowered our self-concept. These experiences produced strong emotional reactions that the brain's amygdala encoded and stored with the cognitive event. These emotional cues are so strong that we often reexperience the original emotion each time we recall the event. Over time, new positive and negative experiences moderate the self-concept and alter how we see ourselves in our world.

Self-Concept and Mindset

One of the major components of our self-concept is *mindset.* Mindsets affect our cognitive processing (Schroder et al., 2014). They develop at a very early age and are the results of interactions with our parents, friends, and elements of our specific culture. These experiences influence us in many ways, including our beliefs about how well we can learn and achieve. Psychologist Carol Dweck has been studying mindsets for years and suggests that they fall into these two basic types: fixed and growth (Dweck, 2017). Individuals with a fixed mindset believe that success comes from one's innate ability. A person either has that ability in a certain domain or does not, and not much can be done about it. You hear a fixed mindset at work when a student says, "I can't do math, and no one in my family can." Students with a fixed mindset avoid challenges for fear of failing, and they give up easily because they do not believe that effort pays off. These behaviors have an impact on their self-concept. On the other hand, students with a growth mindset believe that their success comes from their efforts and persistence. They accept that there may be certain genetic influences, but they rely more on hard work and resilience than on ability for their achievement. These students tend to be more intrinsically motivated to study and learn.

The good news is that teachers can play a significant role in helping students with a fixed mindset develop a growth mindset. Studies reveal that teachers with growth mindsets have a positive and statistically significant association with the development of their students' growth mindsets, particularly for boys (Mesler et al., 2021). It seems clear that students with growth mindsets are more likely to believe that they can achieve in learning and are therefore better able to persist when challenges arise. One must take care, however, not to presume that growth mindsets lead to an inevitable improvement in the students' grades. Studies to date have not shown a strong association between a growth mindset and better grades (e.g., Li & Bates, 2020).

ACCEPTING OR REJECTING NEW LEARNING

Remember that the sensory register and temporary memory systems use past experiences as the guide for determining the importance of incoming stimuli to the individual. Thus, if an individual is in a new learning situation and past experience signals the sensory register that prior encounters with this information were successful, then the information is very likely to pass along to working memory. The learner now consciously recognizes that there were successes with this information and focuses on it for further processing. But if past experiences produced failure, then the sensory register is likely to block the incoming data, just as Venetian blinds are closed to block light. The learner resists being part of the unwanted learning experience and resorts to some other cerebral activity, internal or external, to avoid the situation. In effect, the learner's self-concept has closed off the receptivity to the new information. As mentioned earlier in the discussion of the hierarchy of data processing, when a curriculum concept struggles with an emotion, the emotion almost always wins. Of course, it is possible for the rational system (frontal lobe) to override the emotions, but that usually takes time, conscious effort, and a meaningful reason for doing so.

Let us use an example to explain this important phenomenon. Someone who was a very successful student in mathematics remembers how that success boosted self-concept. As a result, the individual now feels confident when faced with basic mathematical problems. On the other hand, for someone who did poorly as a mathematics student, that lack of success would lower the self-concept. Consequently, such an individual will avoid dealing with mathematical problems whenever possible—a condition known as *math anxiety*. People will participate in learning activities that have yielded success for them and avoid those that have produced failure.

IMPLICATIONS FOR TEACHING

Students who experience self-concept shutdown in the classroom often give signs of their withdrawal—folding their arms, losing themselves in other work, attending to a digital device, or causing distraction. Too often, teachers deal with this withdrawal by reteaching the material, usually slower and louder. But they are attacking the problem from the front end of the information processing system, and this is rarely successful. It is the equivalent of putting a brighter light outside the closed Venetian blinds, hoping the light will penetrate. If the blinds are fully closed and effective, no light will get through, regardless of how bright it may be. In other words, the learner's decision to ignore the material is successful.

The better intervention is to deal with the learner's emotions and convince the learner to allow the perceptual register to open the blinds and pass the information along. But because the self-concept controls the blinds, the learner must believe that participating in the learning situation will produce new successes rather than repeat past failures. When teachers provide these successes, they encourage students to open the sensory register and, ultimately, to participate and achieve in the once-avoided learning process. In short, the self-concept controls the feedback loop and determines how the individual will respond to almost any new learning situation. Recognizing this connection gives teachers new insight on how to deal with reluctant learners.

> *People will participate in learning activities that have yielded success for them and avoid those that have produced failure.*

VARIATIONS IN PROCESSING WITH AGE

The components and dynamics of the processing system remain basically the same throughout our lives. However, there are some variations in students as their brains go through different stages of development and encounter new experiences. Children in preschool and the primary grades have had relatively few experiences that would cause their emerging self-concept to block incoming information. Therefore, these children tend to be open to all types of learning. They see themselves as creative beings exploring a largely unknown environment. Their brains process almost everything in an effort to establish neural networks and patterns that will help their owners survive and make sense of the world around them.

Adolescence is a busy time for the brain. In addition to monitoring physical changes, it needs to manage a rapidly growing collection of neural networks. Some of these networks are having an impact on the developing self-concept. Together with the emotional (limbic) brain, they begin to exert their influence in accepting or resisting new learnings. In the midst of all this activity, the social brain is energized and directing more of the brain's attention resources to social needs than to course content. Meanwhile, learning preferences are developing and affecting how information will be processed.

LEARNING PROFILES (STYLES)

Experienced teachers have recognized for years that students learn in different ways. Several decades ago, psychologists and educators began to talk about "learning style" models that could describe the preferences that students had while learning. Dunn and Dunn (1993) developed one popular model in the 1970s that was organized around five categories: environmental, emotional, sociological, physiological, and psychological preferences. The Dunns suggested that students could achieve more if teachers tailored their instructional strategies to a student's individual learning style. Over the years, several more models emerged, and learning style was also used to describe other variables involved in learning, such as intelligence preferences and cultural influences (Gardner, 1993). Because of the proliferation of these models and the inclusion of other factors, the term "learning style" itself suffered from a vagueness that challenged researchers who wanted to determine whether its components really had an impact on student achievement.

The whole area of learning preferences remains the subject of considerable debate among researchers and educators. There is little argument that people have various internal and environmental preferences when they are learning. Hundreds of books and articles have been written, both supporting and questioning the notion of learning styles and preferences. Research support is weak. In fact, researchers argue that teachers should not be using up valuable time assessing students' learning preferences, but rather should be using that time to design instruction so that it addresses a variety of preferences.

What's Coming Up?

This completes our trip through the information processing model. Remember that the brain is a parallel processor and deals with many items simultaneously. Even though it rejects much data, it always stores some. The next chapter will examine the nature of memory and the factors that determine and help in the retention of learning.

PRACTITIONER'S CORNER

Walking Through the Brain

Directions: In this activity, students/participants will assume the roles of the different parts of the information processing model.

1. Each participant gets one of the following assignments:

   3 to 4 persons for the ***sensory register***

   1 person for the ***immediate memory***

   1 person for the ***working memory***

   3 to 4 persons for the ***long-term storage***

   rest of the group represents ***incoming information***

2. In an open area of the classroom, the participants should arrange themselves in a pattern that approximates the information processing model shown in Figure 2.1.
3. All participants, except those representing incoming information, briefly explain their role and function in the model.
4. The participants representing incoming information then move through the model one at a time, explaining what is happening at each stage.
5. Variations: Replay the activity, demonstrating how information can be accepted or rejected by the sensory register, immediate memory, and working memory. One of the participants representing long-term storage can also represent the feedback loop of past experiences.
6. After demonstrating several different possibilities, discuss how this activity may have enhanced your understanding of the model. Note the positive effect that kinesthetic activities can have on learning new material.

PRACTITIONER'S CORNER

Redesigning the Information Processing Model

This activity gives the students/participants the opportunity to redesign the information processing model explained in this chapter.

Directions: In the area below, redesign the information processing model using a different metaphor (e.g., playing a sports game, taking a vacation, cooking a recipe). Keep the same metaphor for each of the major parts of the model. Be prepared to explain the metaphor and why you chose it.

PRACTITIONER'S CORNER

Developing Students' Growth Mindset

Teachers can have a significant impact on helping students shift from a fixed mindset to a growth mindset and thus improve their motivation and achievement. Dweck (2012/2013, 2017) suggests that teachers consider the following ideas:

- Determine first your own mindset. To do that, go to http://mindsetonline.com/testyour mindset/step1.php. Look at the results and see if you need to develop a growth mindset before trying to teach it to students. Reflect on how you feel about your students. Do you believe there are some who will never get it? Observe your own practices and ask what you need to do to develop or enhance your growth mindset and your teaching ability.
- Teach the student how the brain changes with learning. Explain that abilities are not fixed. When learning something new, the neurons in the brain make new connections that, over time, can enhance their intellectual abilities. This takes effort and persistence that can make you smarter.
- Be sure to emphasize the importance of effort, not ability, when giving feedback on students' work. Focus on their efforts and the learning strategies they used, as well as the progress they have made and what they *specifically* need to do in the future to improve.
- Present yourself as a mentor and resource for learning rather than as one who judges a student's intellectual abilities.
- Be aware of negative stereotypes. There are achievement gaps between Black and white students and between males and females in mathematics and science. People in those groups often have a fixed mindset about their abilities. They believe they cannot learn something simply because they belong to that group. Remind these students that they can master the necessary skills with the right strategies, the right work ethic, and proper instruction.
- Caution: Be sure to explain that tests do *not* measure their potential to achieve in the future.

PRACTITIONER'S CORNER

Developing a Classroom Climate Conducive to Learning

Learning occurs more easily in environments free from threat or intimidation. Whenever a student detects a threat, thoughtful processing gives way to emotion or survival reactions. Experienced teachers have seen this in the classroom. Under pressure to give a quick response, the student begins to stumble, stabs at answers, gets frustrated or angry, and may even resort to violence.

There are ways to deal with questions and answers that reduce the fear of giving a wrong answer. The teacher could

- supply the question to which the wrong answer belongs (e.g., "You would be right if I had asked . . .");
- give the student a prompt that leads to the correct answer; or
- ask another student to help.

Threats to students loom continuously in the classroom. The teacher's capacity to humiliate, embarrass, reject, and punish constitutes a perceived threat. Many students even see grading more as a punitive than as a rewarding process. Students perceive threats in varying degrees, but the presence of a threat in *any* significant degree impedes learning. One's thinking and learning functions operate fully only when one feels secure.

Teachers can make their classrooms better learning environments by avoiding threats (even subtle intimidation) and by establishing democratic climates in which students are treated fairly and feel free to express their opinions during discussions. In these environments, students

- develop trust in the teacher;
- exhibit more positive behaviors;
- are less likely to be disruptive;
- show greater support for school policy; and
- sense that thinking is encouraged and nurtured.

FOR FURTHER DISCUSSION

What kinds of emotions in school could interfere with cognitive processing (i.e., have a negative effect on learning)?

What strategies and structures can schools and teachers use to limit the threat and negative effects of these emotions?

What factors in schools can foster emotions in students that promote learning (i.e., have a positive effect)?

What strategies have you used to encourage the positive emotions that promote learning?

PRACTITIONER'S CORNER

Using Humor to Enhance Climate and Promote Retention

Research shows that humor has many benefits when used frequently and appropriately in the classroom and other school settings (e.g., Jeder, 2015; Martin & Ford, 2018).

PHYSIOLOGICAL BENEFITS

- **Provides more oxygen**. Brain cells need oxygen and glucose for fuel. When we laugh, we get more oxygen into the bloodstream, so the brain is better fueled.
- **Causes an endorphin surge**. Laughter causes the release of **endorphins** in the blood. Endorphins are the body's natural painkillers, and they also give the person a feeling of euphoria. In other words, the person enjoys the moment in body as well as in mind. Endorphins also stimulate the brain's frontal lobes, thereby increasing the degree of focus and amount of attention time.
- **Moderates body functions**. Scientists have found that humor decreases stress, modulates pain, decreases blood pressure, relaxes muscle tension, and boosts immune defenses. These are all desirable outcomes.

PSYCHOLOGICAL, SOCIOLOGICAL, AND EDUCATIONAL BENEFITS

- **Gets attention.** The first thing a teacher has to do when starting a lesson is to get the students' attention or focus. Because the normal human brain loves to laugh, starting with a humorous tale (such as a joke, pun, or story) gets the learner's attention. Self-deprecating humor ("You won't believe what happened to me this weekend") is particularly effective with teens.
- **Creates a positive climate.** Students are going to be together in a classroom for about 180 days. We need to find ways to help this increasingly diverse student population get along. When people laugh together, they bond and a community spirit emerges—all positive forces for a climate conducive to learning.
- **Increases retention and recall.** We know that emotions enhance retention, so the positive feelings that result from laughter increase the probability that students will remember what they learned and be able to recall it later (e.g., Saraa-Zawyah et al., 2013).
- **Improves everyone's mental health.** Schools and all their occupants are under more stress than ever. Taking time to laugh can relieve that stress and give the staff and students a better mental attitude with which to accomplish their tasks. Let's take our work seriously but ourselves lightly.
- **Provides an effective discipline tool.** Good-natured humor (not teasing or sarcasm) can be an effective way of reminding students of the rules without raising tension in the classroom. Laughter also dampens hostility and aggression. Teachers who use appropriate humor are more likable, and students have a more positive feeling toward them. Discipline problems, therefore, are less likely to occur.

Use Humor as Part of Lessons. Humor should not be limited to an opening joke or story. Because of its value as an attention-getter and retention strategy, look for ways to use humor within the context of the learning objective. Textbooks often lack humor, so use humorous examples and video clips from the internet that relate to the learning. Include humorous assignments in homework to maintain student interest. Several books on the market give many helpful suggestions on how to get students to use humor in lessons.

Administrators and Humor. Administrators also need to remember the value of humor in their relationships with staff, students, and parents. As leaders, they set the example. In meetings and other settings, they can show that humor and laughter are acceptable in schools and classrooms. Studies show a principal's sense of humor can motivate teachers (e.g., Akyol & Gündüz, 2014).

SOME BARRIERS TO HUMOR IN CLASSROOMS

- **"I'm not funny."** Some teachers want to use humor in the classroom but don't perceive themselves as jokesters. They'll say, "I'm just not funny" or "I can't tell a joke." But the teacher doesn't have to be funny, just the material—and there's plenty of it. Books on humor are available in local stores, as well as video clips on YouTube, and don't forget that students themselves often provide humor by their responses in class and answers on tests. Be certain that you use this material appropriately, ensure anonymity, and avoid teasing or sarcasm.
- **"Students won't enjoy it."** Secondary teachers, particularly, believe that students will not find humor in corny jokes or that they are too sophisticated to laugh. But everyone likes to laugh (or groan) at humor. I suggest starting each class period with humor for three weeks, then stopping. I am certain that students will say, "Hey, where's the joke?"—evidence that they *were* listening.
- **"It takes too much time."** This is a common concern. Secondary teachers often feel so pressured to cover curriculum material that they are reluctant to give time to what may seem like a frivolous activity. On the other hand, humor is an *efficient* as well as effective way to gain students' attention and improve retention of learning. It really is a useful investment of time.

Avoid Sarcasm. All of the wonderful benefits mentioned earlier are the result of using wholesome humor that everyone can enjoy and not sarcasm, which is inevitably destructive to someone. (Did you know that the word "sarcasm" comes from the Greek "to bite flesh"?) Some well-intentioned teachers say, "Oh, I know my students very well, so they can take sarcasm." But more than ever, today's students are coming to school looking for emotional support. Sarcasm is one of the factors that can undermine that support and turn students against their peers, the teacher, and the school. When a student who is the object of sarcasm smiles, you really do not know if the student thinks the comment is humorous or is, instead, plotting revenge. Besides, there are plenty of sources of good classroom humor without sarcasm.

PRACTITIONER'S CORNER

Increasing Processing Time Through Motivation

Working memory is a temporary memory, so items have a limited time for processing. But the longer an item is processed (or rehearsed), the greater the probability that sense and meaning may be found and, therefore, that retention will occur. One way to increase processing time is through **motivation**, which is essentially an emotional response. Not surprisingly, recent research has validated long-standing beliefs that motivation is a key to the amount of attention devoted to a learning situation.

Motivation can come from within the individual, called *intrinsic motivation*, when an activity is related to a person's needs, values, interests, and attitudes. People spend hours on their hobbies because intrinsic motivation brings them joy and satisfaction. These internal attributes are so deeply rooted that they are difficult to change. But they can change over time.

Motivation that comes from the environment, such as rewards and punishment, is called *extrinsic motivation*. External motivators are used to control and reward behavior. Grades, stars, and praise are examples of external motivators used in schools. Although these incentives serve a purpose, they have little relationship to the internal process of learning. It's no secret that focus and learning occur best when the learner is intrinsically motivated. External motivators can be of value by getting students started on a topic so that they can move toward intrinsic rewards.

Here are a few ideas about motivation for teachers to consider (Anderman & Gray, 2015; DePasque & Tricomi, 2015):

- **Generate interest.** If the learner is interested in the item, then the processing time can be extended significantly because the learner is dealing with the item in different ways and making new connections with past learnings that once were also of interest. The working memory is seeking ways to use this new learning to enhance the usefulness of the past learning. We all know students who won't give us five minutes of their undivided attention in class but who spend hours working on a stamp collection, playing video games, or repairing a carburetor.

Teachers can identify these interests by having their students complete interest inventories at the beginning of the school year. The information gathered from these surveys can help teachers design lessons that include references to student interests as often as possible. Guidance counselors can provide information on the types and sources of interest inventories.

Today's novelty-seeking brain wants to get actively involved in the learning process. Studies show that when students have input in the teaching–learning process, they feel more competent and more motivated to persist in the learning (e.g., Kulakow, 2020). Active learning involves choices and actions that the learner finds pleasurable and effective for developing an understanding of the big picture as well as the relationship between and among the components of the learning objective. This approach stimulates intrinsic motivation and interest. Teachers, then, should

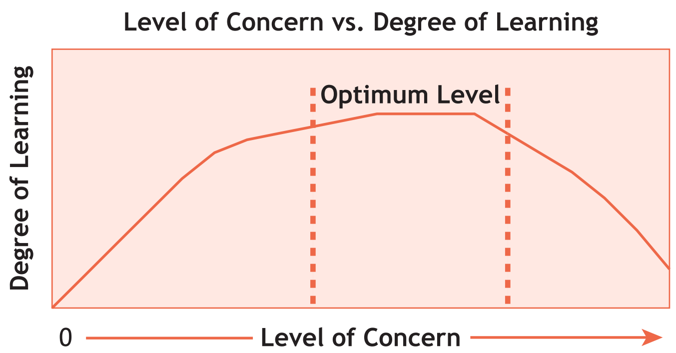
  – make clear what the students should be able to do when the lesson objective is accomplished;
  – include provocative ideas and challenging activities;

- involve the students in developing the criteria that will be used to assess their competency (e.g., assessment rubrics);
- demonstrate how closely the content is connected to the real world; and
- give students choices in selecting activities and questions to pursue.

- **Establish accountability.** When learners believe they will be held accountable for new learning, processing time increases. High school students have little difficulty staying on task in driver education classes. Not only do they have interest, but they also know they will be legally accountable for their knowledge and skills long after they complete the license tests.
- **Provide feedback.** Research studies clearly show that when students get prompt, specific, and corrective feedback on the results of their thinking, they are more likely to continue processing, make corrections, and persist until successful completion (Hattie, 2012). Formative assessments, such as frequent brief quizzes that are carefully corrected and returned promptly, are much more valuable and effective learning tools than summative assessment, such as the unit test, and are more likely to help students be successful. This success will improve self-concept and encourage them to try more difficult tasks. Computers and similar technology are motivating because they provide immediate and objective feedback and allow students to evaluate their progress and understand their level of competence.

Another effective strategy suggested by Hunter (2004) for increasing processing time through motivation is called *level of concern*. This refers to how much the student cares about the learning. We used to think that if the students had anxiety about learning, then little or no learning occurred. But there is helpful anxiety (desire to do well), and there is harmful anxiety (feeling threatened). Having anxiety about your job performance will usually get you to put forth more effort to obtain positive results. When you are concerned about being more effective (helpful anxiety), you are likely to learn and try new strategies. This is an example of how emotions can increase learning.

Level of concern for learning is particularly important to examine in this post-COVID environment. The pandemic greatly upset traditional schooling, and many students worry about where they stand academically because of extended online instruction. Getting students to shift their levels of concern from the stress of distance learning to the in-class lesson objective will take patience, perseverance, and the need to make clear why the lesson objective is relevant.



The graph shows that, as the level of concern increases, so does the degree of learning. If the stress level gets too high, our focus shifts to the emotions and the consequences generated by the stress, and learning fades. Students need a certain level of concern to stimulate their efforts to learn. When there is no concern, there is little or no learning. But if there is too much concern, anxiety shuts down the learning process, and adverse emotions take over. The teacher then has to seek the level of concern that produces the optimum processing time and learning. Hunter (2004) offers four ways to raise or lower the level of concern in a lesson:

- **Consequences.** Teachers raise the level of concern when they say, "This is going to be on the test," and lower it with "Knowing this will help you learn the next set of skills more easily."
- **Visibility.** Standing next to a student who is off task will raise that student's concern; moving away from an anxious student will lower concern. Telling students their work will be displayed can also raise concern. Use this strategy with care.
- **Amount of time.** Giving students only a little time to complete a learning task will raise concern; extending the time will lower it.
- **Amount of help.** If students have little or no help while completing a learning task, concern rises. On the other hand, if they have quick access to help, concern lowers. This can be a problem, however. If students can always get immediate help, either from a person or by "Googling," they may become dependent on those sources and never learn to solve problems for themselves. There comes a time when the teacher needs to reduce the help and tell the students to use what they have learned to solve the problem on their own or in a group.

REFLECTIONS

A. What types of class activities increase the level of concern beyond the optimum level?

B. What strategies lower the level of concern raised by the activities in your answers to Question A?

PRACTITIONER'S CORNER

Creating Meaning in New Learning

Meaning refers to the relevance that students attach to new learning. Meaning is not inherent in content; rather, it is the result of how the students relate the content to their past learnings and experiences. Questions such as "Why do I need to know this?" reveal a learner who is having difficulty determining the relevance of the new topic. Here are a few ways teachers can help students attach meaning to new learning.

- **Modeling.** Models are examples of the new learning that the learner can perceive in the classroom rather than relying on experience. Models can be concrete (an engine) or symbolic (a map). The internet can be a valuable source of models when a real one is impractical. To be effective, a model should do all of the following:
  - Accurately and unambiguously highlight the critical attribute(s) of new learning. A dog is a better example of a mammal than is a whale.
  - Be given first by the teacher to ensure that it is correct during this period of prime time when retention is highest.
  - Avoid controversial issues that can evoke strong emotions and redirect the learner's attention.
- **Using examples from students' experience.** These allow students to bring previous knowledge into working memory to accelerate making sense of and attaching meaning to the new learning. Make sure that the example is clearly relevant to the new learning. This is not easy to do on the spot, so examples should be thought out in advance when planning the lesson.
- **Creating artificial meaning.** When it is not possible to identify exemplary elements from student experience to develop meaning, we can resort to other methods. **Mnemonic** devices help students associate material so they can remember it. Examples are HOMES to remember the Great Lakes and "Every good boy does fine" for the musical notes *e*, *g*, *b*, *d*, and *f* (see Chapter 3).

PRACTITIONER'S CORNER

Using Closure to Enhance Sense and Meaning

Closure describes the covert process whereby the learner's working memory summarizes for itself its perception of what has been learned. It is during closure that a student often completes the rehearsal process and attaches sense and meaning to the new learning, thereby increasing the probability that it will be retained in long-term storage.

- **Initiating closure.** The teacher gives directions that focus the student on the new learning, such as "I'm going to give you about two minutes to think of the three causes of the Civil War that we learned today. Be prepared to discuss them briefly." In this statement, the teacher told the students how much quiet time they have for the cerebral summarizing to occur and identified the overt activity (discussion) that will be used for student accountability. During the discussion, the teacher can assess the quality and accuracy of what occurred during closure and make any necessary adjustments in teaching.
- **Closure is different from review**. In review, the teacher does most of the work, repeating key concepts made during the lesson and rechecking student understanding. In closure, the student does most of the work by mentally rehearsing and summarizing those concepts and deciding whether they make sense and have meaning. Closure activities are an excellent type of formative assessment.
- **When to use closure**. Closure can occur at various times in a lesson.
  - It can start a lesson: "Think of the two causes of the Civil War we talked about yesterday and be prepared to discuss them."
  - It can occur during the lesson (called *procedural closure*) when the teacher moves from one sublearning to the next: "Review those two rules in your mind before we learn the third rule."
  - It should also take place at the end of the lesson (called *terminal closure*) to tie all the sublearnings together.

Closure is an investment that can pay off dramatically in increased retention of learning.

PRACTITIONER'S CORNER

Testing Whether Information Is in Long-Term Storage

Information that the learner processes during a lesson remains in working memory, where it eventually will be dropped out or saved for long-term storage. Just because students act as if they have learned the new information or skill doesn't mean it will be transferred to long-term storage. Extensive research on retention indicates that 70 to 90 percent of new learning is forgotten within 18 to 24 hours after the lesson. Consequently, if the new learning survives this time intact, it is probably destined for long-term storage during sleep and will not deteriorate further (e.g., MacDonald & Cote, 2021).

This time requirement confirms that the processing and transferring between working memory and long-term storage needs adequate time for the encoding and of the new information into the storage networks. Thus, assuming the learner has slept, tomorrow is the earliest reliable time we can confirm that what was learned today has likely been retained.

How to Test. If teachers want to assess whether information actually has been transferred to long-term storage, the assessment needs to

- be given no sooner than 24 hours after the learning;
- test precisely what should have been retained; and
- come as a surprise to the learner, with no warning or preparation time.

Rationale. If the learners have warning about the test, they are likely to review the material just before the test. In this case, the test may determine the amount of information the learners were able to cram and hold in working memory and not what they have recalled from long-term storage. While testing without warning may seem insensitive, it is the only way teachers can be sure that long-term storage was the source of the test information that the learners provided. Unannounced quizzes, then, are formative assessments that should help students assess what they have remembered, rather than be a classroom management device to get students back on task.

Misuse of Tests. Some teachers use unannounced tests as punishment to get students back on task. This is a misuse of a valuable tool. Another approach is for teachers to

- establish sense and meaning to increase the probability that retention will occur;
- explain to students that unannounced assessments help them see what as well as how much they have retained and learned over a given period; and
- ensure that the test or quiz matches the rehearsal when it was first taught. If the learning required essentially rote rehearsal, give a rote type of test. If it required elaborate rehearsal, use a test that allows the students more flexibility in their responses.

Using the Test Results. It is important that teachers complete these tasks after the test:

- Analyze immediately the results of the test to determine what areas need to be retaught or practiced. If some students forgot parts, consider forming cooperative learning groups that focus on reteaching the forgotten areas.
- Record the grades of only a small portion of these unannounced assessments. Rather, ask students to share their results and discuss in a think-pair-share format what strategies the students used to remember their correct responses. In this way, students talk about their memory processes and have a better understanding of how they learn and remember.
- Decide whether memory strategies such as concept maps, mnemonics, or chunking (see the following chapters) can help in retention.

The analysis might also reveal areas of the curriculum to be reworked or updated for relevance, or it might show that the lesson should be retaught in a different way. A task analysis on a failed lesson is a good way to detect false assumptions about learning that the teacher may have made, and it recasts the lesson into a new presentation that can be more successful and interesting for both students and teacher.

Using tests, especially formative assessments, as tools to help students to be right rather than to catch them being wrong will create a supportive learning climate that results in improved student performance.

PRACTITIONER'S CORNER

Using Synergy to Enhance Learning

Synergy describes how the joint actions of people working together increase each other's effectiveness. This strategy gets students moving and talking while learning. It is effective because it is novel, is multisensory, uses active participation, is emotionally stimulating, and encourages socialization. Each participant ends up having a better understanding as a result of this interaction (synergy). It can be used from the primary grades to graduate school. Here are the guidelines:

- **Provide adequate time for reflection.** After teaching a concept, ask students to quietly review their notes and be prepared to explain what they have learned to someone else. Be sure to allow sufficient time for this mental rehearsal to occur (usually one to three minutes, depending on the complexity of the topic).
- **Model the activity.** Working with a student, show the students how you want them to behave and interact during the activity.
- **Get students to stand, move, and deliver.** Ask students to walk across the room and pair up with someone they do not usually work with or know very well. They stand face to face and take turns explaining what they have learned. They add to their notes anything their partners have said that they do not have. When done, all students end up with more information and ideas than they would have had if they worked alone. If they cannot agree or don't understand something, they are to ask the teacher about it when the activity is over. (*Note*: Make sure students stand face to face—rather than just looking at each other's notes—so that they must talk to their partners. Allow pairs only—one trio, if you have an uneven number of students.)
- **Keep in motion.** Move around the room, using your proximity to help students stay on task. Answer questions to get them back on track, but avoid reteaching the lesson. Otherwise, students will become dependent on your reteaching rather than on each other's explanations.
- **Provide enough time and adjust as needed.** Allow adequate time for this process to be effective. Start with a few minutes, adding more time if they are still on task and reducing the time when you sense they are done.
- **Ensure accountability.** To help keep students on task, tell them that you will call on several students at random when the activity is over to explain what they discussed.
- **Clarify any misunderstandings.** Ask if there were any misunderstandings or items that need further explanation, and clarify them. An inviting statement would be "Is there anything I need to clarify?" rather than "Is there anything you didn't understand?"
- **Use variety for the pairing.** You can pair students by birth week or month, hair or eye color, height, musical cues, similar first names, and so on. Aim for random pairing as much as practicable to enhance socialization (because students tend to work more with their friends) and to avoid monotony.

SOME POTENTIAL BARRIERS TO USING SYNERGY

- **"The teacher should be talking."** The long-standing practice of the teachers being the "deliverers" of information is tough to overcome. For that reason, some teachers are uncomfortable with this activity because they are not "working" (read "talking"). But one of the reasons this activity can be so effective is because it shifts the work to the students' brains, increasing the likelihood that they will find sense and meaning in the new learning.
- **"It takes too much time."** The question is "What would the teacher be doing otherwise? More talking?" This is a useful investment of time because the students are talking about the lesson, thereby enhancing learning and retention.
- **"The students will get off task."** This is a common and realistic concern. However, off-task behavior can be reduced significantly if the teacher continually moves around the room, listens in and asks questions of the student pairs, and holds them accountable for the learning at the end of the activity.

PRACTITIONER'S CORNER

NeuroBingo

Directions: In this activity, the entire group gets up and moves around. Each person tries to find someone who can answer one of the questions in a box. The person who answers the question initials the box. The object is to get a bingo pattern (horizontally, vertically, or diagonally). No person may initial the same sheet twice. Time limit: 15 to 20 minutes, depending on the size and age of the group.

Find a person who is able to . . .

Explain the function of the sensory register	Explain the importance of sense and meaning to learning	Define windows of opportunity	Explain how the brain prioritizes incoming information	Explain the functions of the frontal lobes
State the two functions of the hippocampus	Tell you the function of immediate memory	Explain the function of the amygdala	Explain what is meant by the "novel" brain	Provide an example of how self-concept affects learning
Relate the cognitive belief system to learning	Tell you the functions of the cerebellum	Tell you the functions of the cerebrum	Describe the time limits of working memory	Explain synapses
Explain the meaning of sensory preferences	Describe the capacity limits of working memory	Explain what is meant by emotional control	Explain the function of neurotransmitters	Explain the function of long-term memory
Explain the value of humor in learning	Name the five senses	Describe the sources of brain research	Explain closure	Describe a neuron

CHAPTER 2: HOW THE BRAIN PROCESSES INFORMATION

KEY POINTS TO PONDER

Jot down on this page key points, ideas, strategies, and resources you want to consider later. This sheet is your personal journal summary and will help to jog your memory.