I still remember the lecture of my life.

I had taught biochemistry for many years, and I knew it backward and forward. So I agreed with no hesitation when my colleague, Chris, asked me to fill in for him on the spur of the moment. He wanted me to lecture about mitochondria, the so-called “power plants” of the cell, and there was no subject I understood better.

I was totally relaxed as I walked into the class. This was a group of premedical students, and as usual they were wound up and ready to go—and I was ready for them!

In the next fifty minutes, I gave a brilliant lecture on how cells get their energy from sugars and fats. I had no notes, but I covered the board systematically from left to right as the period progressed. Everything was organized in my head, and it just poured out the end of that piece of chalk. Nuances were crystal clear. The underlying concepts were powerful and yet obvious. I was hot!

At the end of class, I put my chalk down, dusted my hands on my pants, and asked for questions. I was slightly surprised that there weren’t any, but I attributed that to the clarity of my lecture. Only one
student stayed, and that was just to butter me up. “That was a won-
derful lecture,” she said. “I think I really understood!”

It turned out that Chris needed me for the next class, too, so I used
my second meeting with his students to check out what they had
learned from my brilliant lecture. And, naturally, I wanted them to see
how much they had learned!

You may have guessed the outcome already. The lecture of my life
was followed by one of the greatest surprises of my life. As I probed
their understanding with increasingly easier questions, I was met with
complete silence. Even my student fan had nothing to say.

Finally, I was relieved to see a hand go up at the back of the room.
“Yes?” I responded eagerly. “Dr. Zull,” he said, “could you explain
about mitochondria again?”

* * *

In chapters 2 and 3 I talked about the brain’s natural cycle of learn-
ing and the idea that the back and front parts of the cortex play much
different roles in this cycle. I also suggested that teachers should bal-
ance their teaching so that students use both the front and back cortex.
And I promised you that I would come back to this and talk more
about my ideas of how to teach in that way.

Now I will try to deliver on that promise. This and each of the fol-
lowing chapters will focus on how teachers can challenge a particular
part of the cerebral cortex.

This chapter is about the part of the back cortex that first receives
sensory input, the so-called sensory cortex. Actually the sensory input
different sense organs goes to different parts of the brain, so I am
not referring to just one part of the cortex when I use the term sensory
brain. Rather I am talking about any region of cortex that is the first to
receive input from one of the senses. For example, the auditory cortex
and the visual cortex are both part of the sensory brain.

In terms of the learning cycle, the sensory brain is where our con-
crete experience is first recorded in the cortex. The sensory brain gath-
ers the raw materials for reflection, abstraction, and action.

We can underestimate the richness of these raw materials. Ackerman
is right when she says that the world is “sense-luscious.” As we live our
lives and have our experiences, our brains are literally awash in signals
both from outside and inside our bodies. One important thing we will
see in this chapter is how powerful our sensory brain is. There is really no need to invent any special, nonphysical theories about how we sense the world. Our physical brain is more than up to the task.

Even though we live in a luscious mix of light, sound, and sensation, I am going to focus mostly on sensory experience through light—the sense of vision. The basic ideas we will encounter are illustrated best by vision, and once we see how we see, it is easy to extend those concepts to the other senses. Vision is central to any concrete experience that we have. In many ways, our brain is a “seeing” brain.

**Revisiting the Back Brain**

Let’s review what we have said so far about the back cortex, using the illustration below. During concrete experience, physical information from the world and from our bodies enters the brain through the sense organs (eyes, ears, nose, skin, mouth, internal organs, joints, and muscles). It is then sent in parallel to the emotion monitor (amygdala) and the specific parts of the cortex for each of the senses (visual cortex, auditory cortex, somatosensory cortex, etc.). If the amygdala recognizes the experience as dangerous, it will trigger an instinctive body action, such as jumping back or freezing. That is the extreme response. Normally, both the emotional and cognitive content of experience are sent on to the cortex to be processed by the integrative cortex in the parietal and temporal lobes. This is where cognitive meaning begins to form. In this chapter we will talk mostly about the sensing part of this process, the part that proceeds to integration and meaning.
Seeing Things

When we understand something, we say, “I see.” This is no accident. The brain’s ability to visualize is arguably the most significant aspect of cognition. When we try to help people learn, we want them to “get the picture.”

Thus, we will begin our discussion of the sensory brain with vision. What happens in our brain when we see things?

Part of the answer to this question is that different neurons in the visual brain see different parts of things. The brain first senses the visual world in little bits, but each bit is detected at the same time. We say that the information for each bit is sent in parallel with that for the other bits.

This “disassembly” of visual information actually begins in the eyes, even before any signals reach the brain. Certain cells in the eye sense the color of objects, and other cells sense the form of objects. Each of these two types of cells sends its signals to different neurons in the sensory brain. Still, the information for color and form all arrive at once in the brain because they travel on parallel pathways.

The first neurons in the visual cortex to receive signals from the eyes respond to specific aspects of that input. To register the form of something, the bits of information consist of edges, or lines, which run at different angles. Added up, they produce an outline of objects and features in the visual field. Basically, every object we see becomes a set of lines, or edges. For example, when we look at a window, our brain sees vertical and horizontal edges for the window frame. Certain neurons in the brain respond to the vertical edges, and other neurons respond to the horizontal ones. And if through that window, we see the branches of a tree angling up from the tree trunk toward the sky, that perception depends on neurons that respond to edges going at an angle.

Details

One way to represent what our early visual cortex “sees” is illustrated below, showing the letters O and C as sets of edges at different angles. This is crude representation but it makes an important point. The difference between the two letters is detected instantly, even though the actual physical difference is very small. Details make all the difference!
Our brains become accustomed to discerning details like this, but they can also make mistakes if we get careless. I was reminded of this recently when my daughter Bess won a small amount of money in the Ohio Lottery. Instead of Bess, her check was made out to Ben. I was puzzled by this, until I wrote the two words side by side and realized what tiny details separate the two words as I had written them:

Bess  Ben

The differences between the letter B in both words were ignored both by my brain and by the brain of the person who wrote out the check. But the differences between the ss and the n were important to each of us. They made the difference between Bess and Ben. I leave it to you. Which is which?

A Teacher Looks for Details

The fact that the brain is fully capable of seeing great detail and nuance is encouraging for teachers. We shouldn’t doubt for a moment that our
learners can see the fine points. And when it seems like they can’t, we should look at ourselves for the remedy. Here is an example.

* * *

I was teaching about energy changes in chemical reactions, which chemists call $\Delta G$. (The “$\Delta$” stands for the “change” in energy, and the G for the amount of energy.) As we got deeper into the subject, I explained that under some special conditions, this energy change is called $\Delta G$ prime, written $\Delta G'$.

This seemed fine with my students until the test came along, and I soon discovered that several of them never even noticed the prime. And when I deducted points for this omission, they accused me of being picky!

I had been called “picky” before. It fits right in with another common accusation, which is that I give my students “busy work.” In both cases, I put importance on something that seemed trivial to my students. The details that I knew were important were hardly visible to them!

This time, rather than shrugging off the indictment, I decided to do something about it. I decided to change my teaching.

The change I made was based on my growing understanding of the sensory brain. I was coming to appreciate its ability to sense even the smallest details, and I decided that my students should be able to focus on those details if I worked harder.

Actually, the changes I made were minimal. First, I just paid more attention to the prime. I wrote it with colored chalk for awhile, and every time I said “delta G prime,” I would stop and say, “delta G priiiiime!” Second, I began to pay more attention to details in my preparation for classes. I consciously looked for places where little things make a big difference. Third, I explained that I was doing this to my students, and I asked them to do it, too.

I was surprised at the effect this had. It became almost a game; who can find the important little things? Who would notice some small thing first? For example, one day a student noticed that I was writing my deltas a little smaller and wondered if this was important. My students began to use their sensory brain in a more effective way. They grew to realize that a detail can mean everything, or it can mean nothing. The trick is to know which is which.
Novice, Expert, and Details

The experience I just described led me to recognize something that seems important. Whether we are an expert or a novice, our brains basically sense the same things. The difference is that the expert knows which part of his sensory data is important and which part isn’t. The brain of the chemist knows that the prime is important, but the size of the delta isn’t. The chemistry novice, on the other hand, sees every little thing as being of equal value. To him, it is still all just sensory input.

We have known this for a long time. In his 1840 essay, On the art of teaching, Horace Mann wrote, “The removal of a slight impediment, the drawing aside of the thinnest veil, is worth more to him [the learner] than volumes of lore on collateral subjects.” And later Mann noted, “the mind of the teacher should migrate, as it were, into those of his pupils.”

This brings us back to the importance of seeing things as the student sees them. We must see through the student’s eyes. This means that we must look back and see our subject as it was at first, when it was just sensory input!

It remains a mystery why some teachers do this well and some don’t do it at all. My guess is that many of us have never even thought of it. And it may be that sometimes we are just carried away by our own engagement with our subject, so much so that we almost forget the student.

In any case, I can testify that a conscious, persistent effort made a difference for me. I am better at seeing what the student sees now that I have thought about it.

Attending

Seeing details requires attention. But paying attention is not easy. Many barriers keep us from paying attention.

One such barrier is the amygdala. As I outlined earlier in this chapter and in chapter 5, sensory input is continually screened for possible negative emotional content by the amygdala. If we instinctively sense difficulty or threat, our actions will not be controlled by our sensory cortex that breaks things down into details, but by our survival shortcut through the amygdala, which is fast but misses details.
Another, possibly even more common, barrier to attending is our own misunderstanding of what it means. What should we do when we pay attention?

At one of our teaching discussions with university faculty members, I asked that very question: “What do you do when you try to pay attention?” They wrote their responses on a slip of paper, which I then read to the group.

Here are a few of them:

“I try to focus on the subject and ignore what is peripheral.”

“I sit still, look right at the person, and listen carefully to their words.”

“I set aside my sexual fantasies and try to focus on what is being said.” (Yes, this was an actual response!)

Clearly, attention is about focus. It also seems to suggest being physically still, which presumably helps us focus. However, as Ellen Langer points out in The Power of Mindful Learning, these notions about paying attention may not work very well. If we look hard at one thing, the image becomes blurred and our mind finds itself in a struggle to just keep focusing. We find ourselves focusing on focusing itself.

This is absolutely biological. Paying attention does not mean unrelenting attention on one focal point. Our brain evolved to notice details by shifting its focus from one area to another, by repeatedly scanning the surroundings. This was better for survival. The brain is more likely to notice details when it scans than when it focuses. We exhaust our neurons if we make a constant demand on the same ones for too long. We rest them by using different ones for a bit and then coming back to the details that seem important.

An example of this is shown in the figure that follows, which is an experiment on the movement of the eyes when people studied a photograph entitled “Girl from Volga.” The strange looking image on the right shows how the eyes move as they focus on different regions of the picture. The lines show the eye movements and the dots are the regions of the picture on which the observer focused (where movement stopped). Thus, the dark areas are the places that were examined the most. The experiment clearly shows that the eyes do not stay focused
on any one area of the photograph for long, but instead jump from place to place, returning more frequently to areas of interest. Rather than holding our eyes still, or boring in on one area, we “study” the picture by moving our eyes.3

Importantly, these eye movements are unconscious. It is just the way our visual brain works. It looks for details, not by attending to one area for a long time, but rather by returning to areas of greatest interest more often.

It seems then, that instead of asking people to pay attention, we might ask them to look at things from many different angles. Instead of sitting still, we might ask them to move around so they can see details. In fact, Langer experimented with this approach. She asked students to study a famous painting by walking back and forth in front of it instead of sitting still. Her experiment was very biological, as you can see. She just took advantage of what the brain does by itself. The outcome seemed good for this theory. Students who studied this way remembered more about the painting than those that sat still in front of it and “paid attention” to it.

Seeing the World Is Mapping the World

We have seen that the visual brain breaks things up into little bits. Now we can turn to what is at once one of the most remarkable, and the most necessary, functions of how the brain organizes these bits.
Basically, the physical arrangement of the neurons that fire when we see an object is a map of the physical structure of the object itself.

It is difficult to explain this effectively with words, so let's use the power of the visual brain. The illustration below depicts one of the experiments that demonstrates this idea. The strange looking object at left is part of the brain of a monkey; it is an actual piece of the visual cortex. The dark spots on this piece of brain show places where the neurons have been particularly active. These are clusters of neurons that have fired frequently while the monkey looked at a specific object. That object was the "half-wheel" shown on the right.

This result is striking. The most active cells are arranged in a geometric pattern that contains all the physical relationships of the image itself! Every line in it has a corresponding line of active neurons in the brain. These lines converge at the center, like those in the image, and they cross one another in an exact replication of the image.

This and other experiments have shown that the visual world is literally and physically mapped in our brains. The networks of neurons that fire when we see something retains the physical relationships that characterize what we see. Our concrete experience of seeing is retained in a concrete form of physically connected neurons in the brain.

What Images Give Us

We can visualize the world with our eyes closed. Neuroscience doesn't have a complete explanation of these images yet, but there is little doubt that they begin with physical maps consisting of connected neurons in the brain. Our brains are full of such networks, and it seems certain that what we call thinking and remembering is based on them.

How rich these images are! We have an image of a person walking, but that image also brings an image for motion itself into our con-
sciousness. An image of two trees beside one another activates the neuronal network for the concept of comparison and for number. An image of one person above another is an image of status. An image of a core in an apple is an image of enveloping, or including. In fact, images give us the concepts on which we construct language itself: verbs, nouns, prepositions (whether one thing is on or beside another), number, gender, and even articles (e.g., whether it was the dog or just a dog).

Physical objects in the world contain conceptual relationships, and so, then, do the neuronal networks of our brain. When we realize the centrality of images, it isn't hard to understand why they are by far the easiest thing for the human brain to remember. Memory experiments with pictures have produced amazing results. For example, people can recall seeing hundreds, even thousands of pictures, even when they have seen the pictures for only a few seconds. Researchers in this field have even suggested that there is no upper limit to the number of pictures that the brain can store!7

Our concrete experience contains much of the information we need for understanding, because it produces images for our brains to analyze, rearrange, manipulate, and turn into action. We have maps of our experience in our brains, and we can run through these maps like the frames of a moving picture. We can switch to a brain video of our life anytime we wish.

The Best Image

One of the most important and powerful aspects of experiential learning is that the images in our brains come from the experience itself. These are by far the richest images. They are undiluted and direct, rather than being transported or filtered through text, film, TV, or lecture. They contain data from all the senses at once, rather than just vision, or just sound. They are “sense-luscious.”

My guess is that this richness influences the emotional brain. Experiences have a “feel” to them, and getting our images by direct experience feels better. “You had to be there,” we say when we are at a loss to convey the entirety of our experience in words.

We are also more likely to trust the sensory input from the experience itself. I suspect that this confidence and trust in our sensory input of the “real thing” has a calming effect on our amygdala. And a calmer amygdala means clearer thinking.
I am reminded of the first time I went to a major league baseball game. The minute I entered the stadium, I sensed electricity in the air. The excitement was palpable. And as I watched the players warm up, I was amazed at the things I sensed. The ball literally whistled through the air. There was incredible beauty in the throwing action of the players, which I had never noticed when I watched games on TV. I could see the completion of the throw and the fluidity of the players as they moved effortlessly into their next motion. It was all one big ballet, and I could sense its wholeness, rather than being limited to what a camera man would choose to show me. There was freedom in this experience. It felt clear, complete, and safe. It was the best image I could have.

Images and Academics

Given the centrality of images, it seems that teachers could make extensive use of images to help people learn. If we can convert an idea into an image, we should do so. And whenever possible, we should require our students to show us their images. It should go both ways.

It is easy to see how certain subjects can be conveyed with images. For example, a great deal of chemistry or biology can be taught completely with images. Other academic subjects may seem more difficult at first, but with creativity it seems likely that almost anything a person would want to learn can be put in the form of an image.

Take mathematics. It is full of images. Calculus produces images of motion and change in motion and of filling up spaces. It may be one of the most image-dependent subjects. And exponents give dramatic images of growth, attrition, explosion and fading away.

The figure that follows illustrates how Rob Dunn, a professor of music at my university, uses images. He converts music into visual maps. This figure represents Rob’s image of the first line in Strauss’ Also sprach Zarathustra.
This image suggests the dynamics, the structure, and even the instruments themselves for this dramatic piece. It begins with the unfolding of a steady sound from the organ, followed by intense horn sounds of different lengths, and ending with six loud drumbeats. The images also suggest the character of the sound. Horns tend to be steady clear bands rather than thin lines, for example. And the images reveal the strategy of the composer in leading the listener, generating excitement, and holding our attention. The visual image is a pedagogical tool for helping students understand the composition and a learning tool for enhancing recall and aiding discovery about the music.

Teaching as Showing

In one of the teaching seminars I recently attended, the speaker described some experiments in which a teacher was helping children learn. The speaker repeatedly said that the teacher provides “support” for the learner. So I asked him what he meant by “support.” What did the teacher actually do?

His answer was amazingly simple. He just said, “show them.” Just let the student see what you consider to be a good answer or a good example.

This rang a bell with me because I had just discovered that the origin of the word teacher seems to be an old English word techen, which meant “to show!” A teacher is one who shows. And, of course, it is entirely consistent with what we have said so far about the visual brain. People see what we show, and when they truly see, when their eyes are opened, they will not need our explanations.

Some of you may protest that a teacher does more than just show things to his students. It doesn’t seem satisfying to think of teaching that way. Anyone can do that!

I think not. If our task is to show, then we must decide what we are going to show and how. Here are some points to consider.

First, we must think carefully about our choices in what we show. It won’t be enough to simply throw something together at the last minute. We have to decide what are the best examples of the things we believe to be most important. What do we really want our students to learn? We need to choose things that show fine points as well as the big picture. We should show what we hope our students will eventually be able to do themselves.
Second, I think we should stay close to the raw image of concrete experience whenever possible. This is the level where we share the most with the student, where our brains come closest to sensing the same thing. We should give the student opportunities to have concrete experiences directly, if possible. Field trips, internships, research projects, true hands-on experiences, collaborations, role playing, and other active learning methods are effective for this very reason. And we should share these experiences with them. The point is to bring the teacher and the student as close together in their concrete experience as possible. Then they will have the same images, and the teacher can understand “what the student already knows,” as we discussed in chapter 6.

Third, we should point out the important parts of images. In many cases we don’t need to say why these parts are of interest or explain things. We just need to encourage students to “Notice this part.” Or ask, “Did you see that part?” Students must notice the important things in order to have useful images. Often, the kind of things we look for have become second nature to us, but by experiencing how we look at the details and seeing what we think is important, our students can begin to form the habits of observation and study that work best in our field.

We can be creative in this “showing.” We can even show students what happens when mistakes are made. For example, we can show them how important it is to add acid to water rather than water to acid. We don’t have to explain it. They will get the picture themselves.

Show more, share more.

Hearing Things

Of course, concrete experience involves more than just seeing things. In fact, one of the most important points about experiential learning is that it engages all of our senses. But when we look at the other senses, we still find ourselves coming back to the main points we found with vision. Let’s look at hearing to illustrate this.

First, our auditory cortex gets its sensory input in little bits, just as with vision. The bits are not edges, but rather frequencies or pitch. Different cells in the ear respond to different pitches, and those cells are wired to specific cells in the auditory cortex. This means that our hear-
ing is also sensitive to details. All the points we made about the importance of details in teaching apply to what the student hears as well as to what he sees.

The brain also attends to sound in a way that is similar to vision. We cannot focus on a particular sound to the exclusion of all others for long. If we do, it loses its significance. Rather, we listen intensely to new sounds for a short time, and then others become more interesting. Our brain expects movement in sound, not fixed attention on one sound.

In fact, if we hear a repeated sound for awhile, it becomes mesmerizing—even tranquilizing. Eventually we begin to ignore it; we literally do not hear it. This is called habituation, and it is a characteristic of neurons and networks of neurons. The synapses actually fire less frequently if we hear the same sound over and over. This explains why we can live in an apartment by a major freeway, and after a few weeks we do not even hear the traffic.

Nothing demonstrates habituation more than a lecture. Unless we break up the sound every few minutes, we are almost certain to induce habituation in a learner's brain. Even when we think we are breaking it up, we all have “our way” of speaking, and the learner gets used to our way, whatever it is, with time. You may have noticed how interest picks up when a new person begins to talk in a class or a lecture. That interest holds up for a short while, even if the speaker ultimately turns out to be “boring.” At first, it is enough that he is new.

A third similarity to vision is that our sense of sound hooks into our image networks. We hear where things are, when they happened, and what they were like. This information is all assembled into a sound map, which, like a vision map, retains many of the actual physical features associated with the experience itself. This is why we can close our eyes, listen, and “picture” what is happening.

The Special Powers of Sound

Sound also has special powers that enrich our concrete experience in ways that vision cannot.

One of these powers is that sound can go around the corner. We can know things that are happening in hidden places if we can hear them. We can make the world aware of our hidden opportunities, or dilemmas, through sound. And we can communicate our identity to an
inattentive world through sound. As in *Horton Hears a Who*, we can cry out, “We are here! We are here!” Even more remarkable, we can call out, “I am here! Jim is here!” This ability is natural and quite sophisticated in the animal world. For example, dolphins seem to communicate their “names” to each other by specific sounds.9

Using sound is also an immensely personal way to communicate. We cry, we laugh, we scream, and we talk. Our friends recognize our voices when we phone them, and they can tell how we feel from the way we sound. Our sounds are generated by our personal voice apparatus, which is of unique shape, size, and conformation. We all sound different. We truly speak with a different voice. And it is hard to hide how we feel when we talk. Despite our best efforts at deception, our feelings often come through.

Because brains can both produce and detect sound, and because it is personal and emotional, sound is a natural vehicle for learning. We see this in the animal world as well. Birds learn their songs from other birds and can learn many different sounds from people. Whale songs seem to evolve with experience, somewhat like language. And preliterate human cultures preserved their history with stories and songs, because they were learned so easily.

A Note on the Other Senses

Even though I said that we would limit ourselves to vision, I can’t end this section on sensory experience without briefly mentioning the potential value of the other senses for the teacher.

Probably one of the reasons that the experience itself is the best sensory input is that it contains more than just sound and sight. Concrete experience produces a rich blend of all the senses. We feel the experience.

There is no more powerful sensory stimulus of the emotions than smell and taste, and as we saw in chapters 4 and 5, emotion is key to learning. So it seems obvious that providing smells and tastes will help people learn. This doesn’t happen often in school learning, but I think it could. For example, we might incorporate the smell of a burning tire when we talk about friction in a physics class. Or we might bring in the odors of putrefying flesh (organic chemists know which chemicals to use) when we describe a civil war battlefield. I am sure you can think
of many other good possibilities for enriching the sensory content of academic subjects.

The sense of touch can also enrich learning. One of my colleagues in the neuroscience department has a sealed plastic bag filled with cooked oatmeal that she uses when she talks about the brain. As she is talking, the bag of oatmeal is being passed around the room, and students who hold and squeeze that bag have a vivid memory of how it would feel to hold a fresh human brain in their hands.

In fact, touch and vision are similar in their mapping capabilities. We can close our eyes and determine how an object would look by feeling it. Blind people use the vision part of their brain when reading Braille, and once a blind person examined how I “look” by touching my face and head.

There is also the sense of body position. We know if we are seated or standing, relaxed or tense, leaning forward or slouching. We feel the weight of objects held in our hand, their heft and balance. And we feel the strain if we are working. This sensory input into our brain becomes a part of our maps of concrete experiences.

Finally, we sense our feelings. We sense whether we are afraid or confident, excited or calm, attracted or repelled in all our experiences. Emotion is part of our sensory experience, providing flavor and quality to the maps in our brain.

I have no doubt that we could do better in helping people learn if we paid more attention to all of these.

The Lecture of My Life and the Concrete Experience of the Classroom

By now it should be easy to see why the lecture of my life was such a dud. I really didn’t consider any of the things we have been talking about in this chapter. My students had very few of the images that I had. There were far too many details they could not notice and had not practiced. And I didn’t show them anything at all about mitochondria; I showed them a professor passionately engaged in his subject. That is not without value, but it does not help a student learn about metabolism!

In many ways, my lecture was like the Gary Larson cartoon in which Ginger the dog is listening carefully and hopefully to her master. He says, “O.K. I’ve had it with you, Ginger! Be a good girl and stay out
of the garbage!” And in the second panel, we see what Ginger hears: “Blah, blah, blah, Ginger! Blah, blah!” Poor Ginger is just getting sound—no meaning.

As we noted in chapter 2, a classroom is, first of all, a concrete experience. The sights and sounds that a student finds there first enter his brain through the senses. It can be mostly sound, even “blah, blah, blah.” It can be a visual image of a teacher either standing still or moving around enthusiastically. It can be an emotional image of support or threat. It can be the sound of chalk on blackboard and the sight of symbols appearing and disappearing on that board. It can be a series of images on a screen in a dark room, accompanied by a droning voice or an excited voice.

Or it can be images, sounds, and feelings that connect with what the student already knows. It can be watching an expert model how to solve a problem. It can be learning. But it is concrete experience; it is sensory input to his brain.

Notes

4. A small amount of radioactive sugar was injected into the bloodstream of a monkey in a darkened room, with the image of the half-wheel projected on the wall. Looking at this image triggered specific neurons in the animal’s visual brain; these specific neurons need more energy than others and thus take up more radioactivity sugar. These more active neuron clusters appear dark in the image. Taken with permission from R. H. B. Tootel and colleagues, J. Neuroscience 8 (1988), p. 1551.
5. The same can be said of sensory input by touch.
7. Ibid., p. 130. Other studies suggested the astonishing result that the human brain can search for more than 50,000 images per second in long-term memory!