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How Can I Teach Students the Skills They Need When Standardized Tests Require Only Facts?

Question: Much has been written about fact learning, most of it negative. The narrow-minded schoolmaster demanding that students parrot facts they do not understand has become a cliché of American education, although the stereotype is neither new nor exclusively American—Dickens used it in *Hard Times*, published in 1854. Concern about fact learning has intensified in the last ten years as the new emphasis on accountability in education has brought an increase in the use of standardized tests. It is too often true that standardized tests offer little opportunity for students to analyze, synthesize, or critique and instead demand the regurgitation of isolated facts. Many teachers feel that time for teaching skills is crowded out by preparation for standardized tests. Just how useful or useless is fact learning?

Answer: There is no doubt that having students memorize lists of dry facts is not enriching. It is also true (though less often appreciated) that trying to teach students skills such as analysis or synthesis in the absence of factual knowledge is impossible. Research from cognitive science has shown that the sorts of skills that teachers want for students—such as the ability to analyze and to think critically—*require* extensive factual knowledge. The cognitive principle that guides this chapter is:

> Factual knowledge must precede skill.

The implication is that facts must be taught, ideally in the context of skills, and ideally beginning in preschool and even before.

> There is a great danger in the present day lest science-teaching should degenerate into the accumulation of disconnected facts and unexplained formulae, which burden the memory without cultivating the understanding.
>
> —*J. D. Everett, writing in 1873*[1]

When I was a freshman in college a guy down the hall from me had a poster depicting Einstein and a quotation from the brilliant, frowsy-haired physicist: "Imagination is more important than knowledge." I could not have said why, but I thought this was very deep. Perhaps I was anticipating what I might say to my parents if my grades were poor: "Sure, I got Cs, but I have *imagination!* And according to Einstein. . . "

Some thirty years later teachers have a different reason to be wary and weary of "knowledge." The national watchword in education is *accountability,* which has translated into state tests. In most states these tests are heavy on multiple-choice questions and usually require straightforward recall of facts. Here are two examples of eighth-grade test items from my home state of Virginia, one from the science test and one from the history test.

Which of the following classification groups contains organisms that have the most characteristics in common?

A. Kingdom
B. Phylum
C. Class
D. Species

Which of these immigrant groups came to America late in the 19th century and helped build the railroads?

A. Germans
B. Chinese
C. Polish
D. Haitians

It's easy to see why a teacher, parent, or student would protest that knowing the answer to a lot of these questions doesn't prove that one really *knows* science or history. We want our students to think, not simply to memorize. When someone shows evidence of thinking critically, we consider her smart and well educated. When someone spouts facts without context, we consider her boring and a show-off.

That said, there are obvious cases in which everyone would agree that factual knowledge is necessary. When a speaker uses unfamiliar vocabulary, you may not understand what he means. For example, if a friend sent you an e-mail telling you she thought your daughter was dating a "yegg," you'd certainly want to know the definition of the word (Figure 1). Similarly, you may know all of the vocabulary

FIGURE 1: If someone said your daughter is dating a *yegg*, you'd certainly want to know whether the word meant "nice-looking fellow," "slob," or "burglar."

words but lack the conceptual knowledge to knit the words together into something comprehensible. For example, a recent copy of the technical journal *Science* contained an article titled "Physical Model for the Decay and Preservation of Marine Organic Carbon." I know what each of these words means, but I don't know enough about organic carbon to understand why its decay or preservation is important, nor why you might want to model it.

The necessity of background knowledge for comprehension is pretty obvious, at least as I've described it so far. You could summarize this view by noting that *to think* is a transitive verb. You need something to think *about*. But you could counter (and I've heard the argument often) that you don't need to have this information memorized—you can always look it up. Recall the figure of the mind in Chapter One (Figure 2, below).

I defined *thinking* as combining information in new ways. The information can come from long-term memory—facts you've memorized—or from the environment. In today's world, is there a reason to memorize anything? You can find any factual information you need in seconds via the Internet—including the definition of *yegg*. Then too, things change so quickly that half of the information you commit to memory will be out of date in five years—or so the argument goes. Perhaps instead of learning facts, it's better to practice critical thinking, to have students work at *evaluating* all the information available on the Internet rather than trying to commit some small part of it to memory.

In this chapter I show that this argument is false. Data from the last thirty years lead to a conclusion that is not scientifically challengeable: thinking well requires knowing facts, and that's true not simply because you need

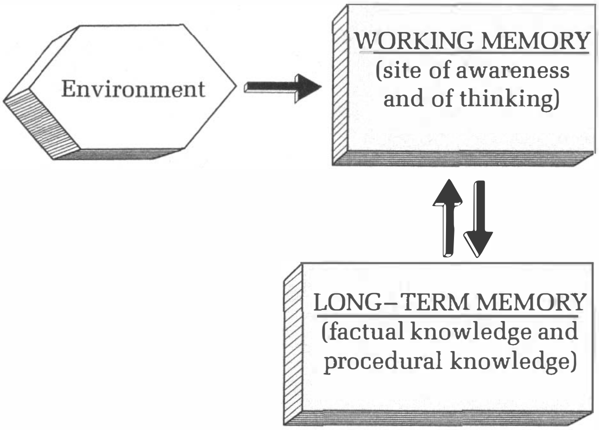

FIGURE 2: Our simple figure of the mind

something to think *about.* The very processes that teachers care about most—critical thinking processes such as reasoning and problem solving—are intimately intertwined with factual knowledge that is stored in long-term memory (not just found in the environment).

It's hard for many people to conceive of thinking processes as intertwined with knowledge. Most people believe that thinking processes are akin to the functions of a calculator (Figure 3). A calculator has available a set of procedures (addition, multiplication, and so on) that can manipulate numbers, and these procedures can be applied to *any set of numbers.* The data (the numbers) and the operations that manipulate the data are separate. Thus, if you learn a new thinking operation (for example, how to critically analyze historical documents), that operation should be applicable to all historical documents, just as a fancier calculator that computes sines can do so for all numbers.

But the human mind does not work that way. When we learn to think critically about, say, the start of the Second World War, it does not mean we can also think critically about a chess game or about the current situation in the Middle East or even about the start of the American Revolutionary War. Critical thinking processes are tied to background knowledge (although they become much less so when we become quite experienced, as I describe in Chapter Six). The conclusion from this work in cognitive science is straightforward: we must ensure that students acquire background knowledge parallel with practicing critical thinking skills.

In this chapter I describe how cognitive scientists know that thinking skills and knowledge are bound together.

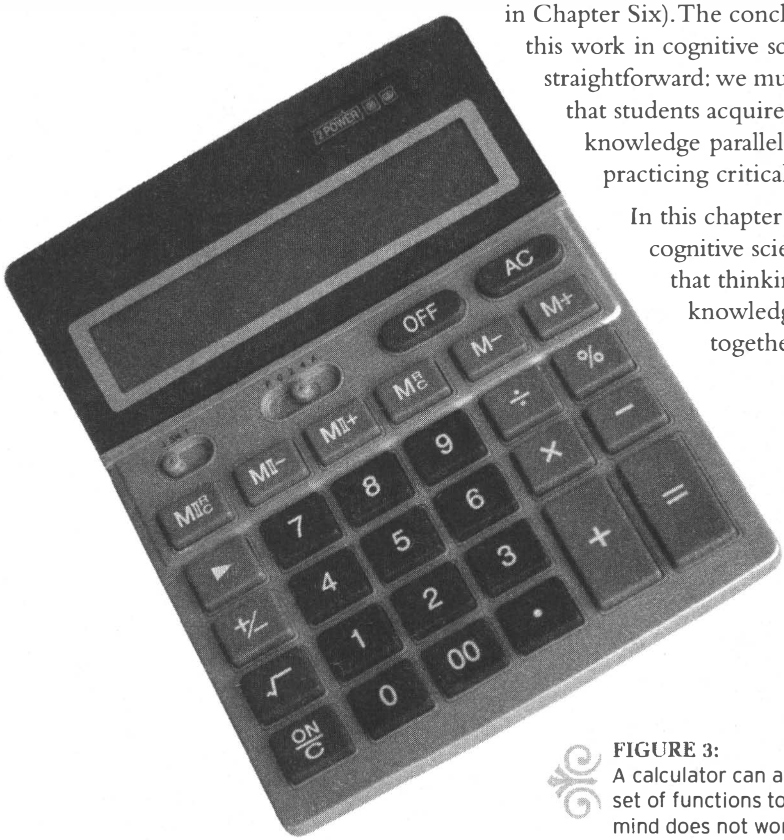

FIGURE 3:
A calculator can apply the same set of functions to any data. The mind does not work that way.

Knowledge Is Essential to Reading Comprphension

Background knowledge helps you understand what someone is talking about or writing. In the last section I gave a couple of rather obvious examples: if a vocabulary word (for example, *yegg*) or a concept (for example, *marine organic compound*) is missing from your long-term memory, you'll likely be confused. But the need for background knowledge is deeper than the need for definitions.

Suppose a sentence contains two ideas—call them A and B. Even if you know the vocabulary and you understand A and B, you still might need background knowledge to understand the sentence. For example, suppose you read the following sentence in a novel:

> "I'm not trying out my new barbecue when the boss comes to dinner!" Mark yelled.

You could say that idea A is Mark trying out his new barbecue, and idea B is that he won't do it when his boss comes to dinner. To understand the sentence, you need to understand the *relationship* between A and B, but not provided here are the two pieces of information that would help you bridge A and B: that people often make mistakes the first time they use a new appliance and that Mark would like to impress his boss. Putting these facts together would help you understand that Mark is afraid he'll ruin the food the first time he uses his new barbecue, and he doesn't want that to be the meal he serves to his boss.

Reading comprehension depends on combining the ideas in a passage, not just comprehending each idea on its own. And writing contains gaps—lots of gaps—from which the writer omits information that is necessary to understand the logical flow of ideas. Writers assume that the reader has the knowledge to fill the gaps. In the example just given, the writer assumed that the reader would know the relevant facts about new appliances and about bosses.

Why do writers leave gaps? Don't they run the risk that the reader *won't* have the right background knowledge and so will be confused? That's a risk, but writers can't include all the factual details. If they did, prose would be impossibly long and tedious. For example, imagine reading this:

> "I'm not trying out my new barbecue when the boss comes to dinner!" Mark yelled. Then he added, "Let me make clear that by *boss* I mean our immediate supervisor. Not the president of the company, nor any of the other supervisors intervening. And I'm using *dinner* in the local vernacular, not to mean 'noontime meal,' as it is used in some parts of the United States. And when I said *barbecue*, I was speaking imprecisely, because I really meant grill, because *barbecue* generally refers to slower roasting, whereas I plan to cook over high heat. Anyway, my concern, of course, is that

> my inexperience with the barbecue (that is, grill) will lead to inferior food, and I hope to impress the boss."

We've all known someone who talks that way (and we try to avoid him or her), but not many; most writers and speakers feel safe omitting some information.

How do writers (and speakers) decide what to omit? It depends on whom they're writing for (or speaking to). Have a look at Figure 4. What would the woman pictured there say if someone asked her, "What are you doing?"

If she were talking to a two-year-old she might say, "I'm typing on a computer." But that would be a ridiculous answer for an adult. Why? Because the typist should assume that the adult knows she's typing. A more appropriate response might be, "I'm filling out a form." Thus we calibrate our answers, providing more or less (or different) information depending on our judgment of what the other person knows, thereby deciding what we can safely leave out and what needs to be explained.*

FIGURE 4:
What would this woman say if someone asked her, "What are you doing?" The answer depends on who asked.

What happens when the knowledge is missing? Suppose you read the following sentence:

> I believed him when he said he had a lake house, until he said it's only forty feet from the water at high tide.

If you're like me, you're confused. When I read a similar passage, my mother-in-law later explained to me that lakes don't have appreciable tides. I didn't have that bit of background knowledge that the author assumed I had, so I didn't understand the passage.

So, background knowledge in the form of vocabulary is not only necessary in order to understand a single idea (call it A), but it's also necessary in order to understand the connection between two ideas (A and B). In still other situations, writers present multiple ideas at the same time—A, B, C, D, E, and F—expecting that the reader will knit them together into a coherent whole. Have a look at this sentence from Chapter Thirty-Five of *Moby-Dick:*

> Now, it was plainly a labor of love for Captain Sleet to describe, as he does, all the little detailed conveniences of his crow's-nest; but

> though he so enlarges upon many of these, and though he treats us to a very scientific account of his experiments in this crow's-nest, with a small compass he kept there for the purpose of counteracting the errors resulting from what is called the "local attraction" of all binnacle magnets; an error ascribable to the horizontal vicinity of the iron in the ship's planks, and in the Glacier's case, perhaps, to there having been so many broken-down blacksmiths among her crew; I say, that though the Captain is very discreet and scientific here, yet, for all his learned "binnacle deviations," "azimuth compass observations," and "approximate errors," he knows very well, Captain Sleet, that he was not so much immersed in those profound magnetic meditations, as to fail being attracted occasionally towards that well replenished little case-bottle, so nicely tucked in on one side of his crow's-nest, within easy reach of his hand.

Why is this sentence so hard to understand? You run out of room. It has a lot of ideas in it, and because it's one sentence, you try to keep them all in mind at once and to relate them to one another. But there are so many ideas, you can't keep them all in mind simultaneously. To use the terminology from Chapter One, you don't have sufficient capacity in working memory. In some situations, background knowledge can help with this problem.

To understand why, let's start with a demonstration. Read the following list of letters once, then cover the list and see how many letters you can remember.

X C N
N P H
D F B
I C I
A N C
A A X

Okay, how many could you remember? If you're like most people, the answer would perhaps be seven. Now try the same task with this list:

X
C N N
P H D
F B I
C I A
N C A A
X

You probably got many more letters correct with this second list, and you no doubt noticed that it's easier because the letters form acronyms that are familiar. But did you notice that the first and second lists are the same? I just changed the spacing to make the acronyms more apparent in the second list.

This is a working memory task. You'll remember from Chapter One that working memory is the part of your mind in which you combine and manipulate information—it's pretty much synonymous with consciousness. Working memory has a limited capacity (as discussed in Chapter One), so you can't maintain in your working memory all of the letters from list one. But you can for list two. Why? Because the amount of space in working memory doesn't depend on the number of letters; it depends on the number of meaningful objects. If you can remember seven individual letters, you can remember seven (or just about seven) meaningful acronyms or words. The letters *F, B,* and *I* together count as only one object because combined they are meaningful.

The phenomenon of tying together separate pieces of information from the environment is called *chunking.* The advantage is obvious: you can keep more stuff in working memory if it can be chunked. The trick, however, is that chunking works only when you have applicable factual knowledge in long-term memory. You will see *CNN* as meaningful only if you already know what CNN is. In the first list, one of the three-letter groups was *ICI.* If you speak French, you may have treated this group as a chunk, because *ici* is French for "here." If you don't have French vocabulary in your long-term memory, you would not treat *ICI* as a chunk. This basic effect—using background knowledge to group things in working memory—doesn't work only for letters. It works for anything. Bridge players can do it with hands of cards, dancing experts can do it with dance moves, and so forth.

So factual knowledge in long-term memory allows chunking, and chunking increases space in working memory. What does the ability to chunk have to do with reading comprehension? Well, I was saying before that if you read ideas A, B, C, D, E, and F, you would need to relate them to one another in order to comprehend their meaning. That's a lot of stuff to keep in working memory. But suppose you could *chunk* A through E into a single idea? Comprehension would be much easier. For example, consider this passage:

> Ashburn hit a ground ball to Wirtz, the shortstop, who threw it to Dark, the second baseman. Dark stepped on the bag, forcing out Cremin, who was running from first, and threw it to Anderson, the first baseman. Ashburn failed to beat the throw.

If you're like me this passage is hard to comprehend. There are a number of individual actions, and they are hard to tie together. But for someone who knows about baseball, it's a familiar pattern, like *CNN.* The sentences describe a double play.

A number of studies have shown that people understand what they read much better if they already have some background knowledge about the subject. Part of the reason is chunking. A clever study on this point was conducted with junior high school students.[2] Half were good readers and half were poor readers, according to standard reading tests. The researchers asked the students to read a story that described half an inning of a baseball game. As they read, the students were periodically stopped and asked to show that they understood what was happening in the story by using a model of a baseball field and players. The interesting thing about this study was that some of the students knew a lot about baseball and some knew just a little. (The researchers made sure that everyone could comprehend individual actions, for example, what happened when a player got a double.) The dramatic finding, shown in Figure 5, was that the students' knowledge of baseball determined how much they understood of the story. Whether they were "good readers" or "bad readers" didn't matter nearly as much as what they knew.

Thus, background knowledge allows chunking, which makes more room in working memory, which makes it easier to relate ideas, and therefore to comprehend.

Background knowledge also clarifies details that would otherwise be ambiguous and confusing. In one experiment illustrating this effect,[3] subjects read the following passage:

> The procedure is actually quite simple. First, you arrange items into different groups. Of course one pile may be sufficient depending on how much there is to do. If you have to go somewhere else due to lack of facilities, that is the next step; otherwise, you are pretty well set. It is important not to overdo things. That is, it is better to do too few things at once than too many.

The passage went on in this vein, vague and meandering, and therefore very difficult to understand. It's not that

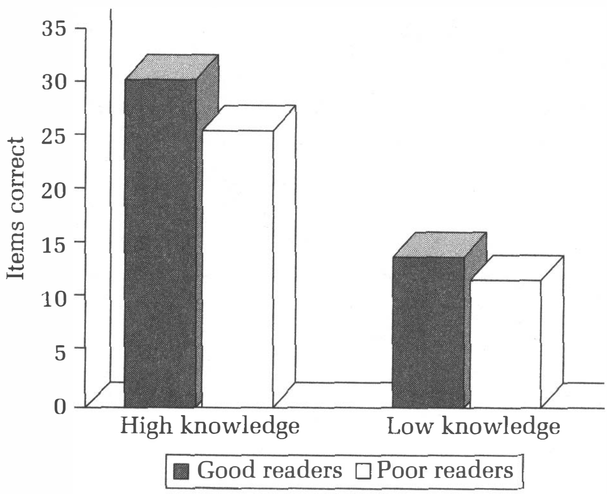

FIGURE 5: Results from a study of reading. As you would predict, the good readers (shaded bars) understood more than the poor readers (unshaded bars), but this effect is modest compared to the effect of knowledge. The people who knew a lot about baseball (leftmost columns) understood the passage much better than the people who didn't know a lot, regardless of whether they were "good" or "poor" readers, as measured by standard reading tests.

you're missing vocabulary. Rather, everything seems really vague. Not surprisingly, people couldn't remember much of this paragraph when asked about it later. They remembered much more, however, if they had first been told that the passage's title is "Washing Clothes." Have another look at the passage now that you know the title. The title tells you which background knowledge is relevant, and you recruit that knowledge to clarify ambiguities. For example, "Arrange items into groups" is interpreted as sorting darks, bright colors, and whites. This experiment indicates that we don't take in new information in a vacuum. We interpret new things we read in light of other information we already have on the topic. In this case, the title, "Washing Clothes," tells the reader which background knowledge to use to understand the passage. Naturally, most of what we read is not so vague, and we usually know which background information is relevant. Thus, when we read an ambiguous sentence, we seamlessly use background knowledge to interpret it, and likely don't even notice the potential ambiguities.

I've listed four ways that background knowledge is important to reading comprehension: (1) it provides vocabulary; (2) it allows you to bridge logical gaps that writers leave; (3) it allows chunking, which increases room in working memory and thereby makes it easier to tie ideas together; and (4) it guides the interpretation of ambiguous sentences. There are in fact other ways that background knowledge helps reading, but these are some of the highlights.

It's worth noting that some observers believe that this phenomenon—that knowledge makes you a good reader—is a factor in the fourth-grade slump. If you're unfamiliar with that term, it refers to the fact that students from underprivileged homes often read at grade level through the third grade, but then suddenly in the fourth grade they fall behind, and with each successive year they fall even farther behind. The interpretation is that reading instruction through third grade focuses mostly on decoding—figuring out how to sound out words using the printed symbols—so that's what reading tests emphasize. By the time the fourth grade rolls around, most students are good decoders, so reading tests start to emphasize *comprehension*. As described here, comprehension depends on background knowledge, and that's where kids from privileged homes have an edge. They come to school with a bigger vocabulary and more knowledge about the world than underprivileged kids. And because knowing things makes it easier to learn new things (as described in the next section), the gap between privileged and underprivileged kids widens.

Background Knowledge Is Necessary for Cognitive Skills

Not only does background knowledge make you a better reader, but it also is necessary to be a good thinker. The processes we most hope to engender in our students—thinking critically and logically—are not possible without background knowledge.

First, you should know that much of the time when we see someone apparently engaged in logical thinking, he or she is actually engaged in memory retrieval. As

I described in Chapter One, memory is the cognitive process of *first* resort. When faced with a problem, you will first search for a solution in memory, and if you find one, you will very likely use it. Doing so is easy and fairly likely to be effective; you probably remember the solution to a problem because it worked the last time, not because it failed. To appreciate this effect, first try a problem for which you *don't* have relevant background knowledge, such as the one shown in Figure 6.[4]

The problem depicted in Figure 6 is more difficult than it first appears. In fact, only about 15 or 20 percent of college students get it right. The correct answer is to turn over the A card and the 3 card. Most people get A—it's clear that if there is not an even number on the other side, the rule has been violated. Many people incorrectly think they need to turn over the 2 card. The rule does not, however, say what must be on the other side of a card with an even number. The 3 card must be flipped because if there is a vowel on the other side, the rule has been violated.

Now let's look at another version of the problem, shown in Figure 7.[5]

If you're like most people, this problem is relatively easy: you flip the beer card (to be sure this patron is over twenty-one) and you flip the 17 card (to be sure this kid isn't drinking beer). Yet logically the 17 card has the same role in the problem that the 3 card did in the previous version, and it was the 3 card that everyone missed. Why is it so much easier this time? One reason (but not the only one) is that the topic is familiar. You have background knowledge about the idea of a drinking age, and you know what's involved in enforcing that rule. Thus you don't need to reason logically. You have experience with the problem and you remember what to do rather than needing to reason it out.

In fact, people draw on memory to solve problems more often than you might expect. For example, it appears that much of the difference among the world's best chess players is *not* their ability to reason about the game or to plan the best move; rather, it is their memory for game positions. Here's a key finding that led to that conclusion. Chess matches are timed, with each player getting an hour to complete his or her moves in the game. On occasion there are so-called blitz tournaments in which players get just five minutes to make all of their moves in a match (Figure 8). It's no surprise that everyone plays a little bit worse in a blitz tournament. What's surprising is that the best players are still the best, the nearly best are still nearly best, and so on.[†] This finding indicates that whatever makes the best players better than everyone else is still present in blitz tournaments; whatever gives them their edge is *not* a process that takes a lot of time, because if it were they would have lost their edge in blitz tournaments.

It seems that it is memory that creates the differences among the best players. When

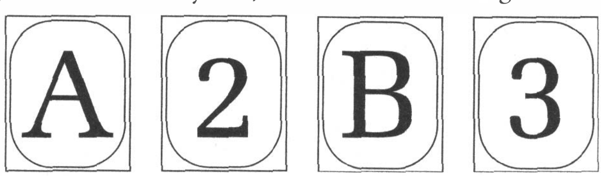

FIGURE 6: Each card has a letter on one side and a digit on the other. There is a rule: *If there is a vowel on one side, there must be an even number on the other side.* Your job is to verify whether this rule is met for this set of four cards, and to turn over the minimum number of cards necessary to do so. Which cards would you turn over?

tournament-level chess players select a move, they first size up the game, deciding which part of the board is the most critical, the location of weak spots in their defense and that of their opponents, and so on. This process relies on the player's memory for similar board positions and, because it's a memory process, it takes very little time, perhaps a few seconds. This assessment greatly narrows the possible moves the player might make. Only then does the player engage slower reasoning processes to select the best among several candidate moves. This is why top players are still quite good even in a blitz tournament. Most of the heavy lifting is done by memory, a process that takes very little time. On the basis of this and other research, psychologists estimate that top chess players may have fifty thousand board positions in long-term memory. Thus background knowledge is decisive even in chess, which we might think is the prototypical game of reasoning.

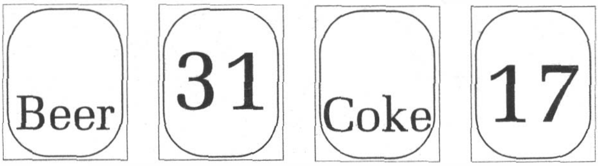

FIGURE 7: You are to imagine that you are a bouncer in a bar. Each card represents a patron, with the person's age on one side and their drink on the other. You are to enforce this rule: *If you're drinking beer, then you must be twenty-one or over.* Your job is to verify whether this rule is met for this set of four people. You should turn over the minimum number of cards necessary to do so. Which cards would you turn over?

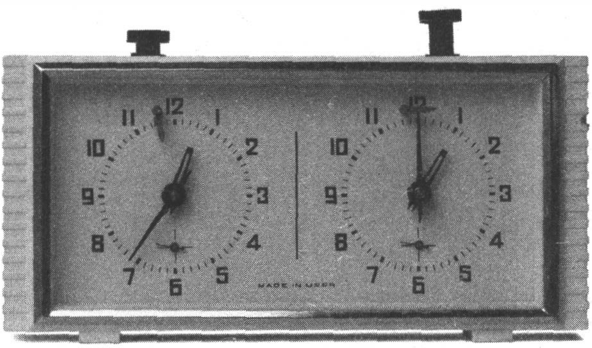

FIGURE 8: A device used to time a chess match. The black hand on each clock counts down the minutes remaining. After making a move, the player pushes the button above his clock, which stops it and causes his opponent's clock to restart. Players set identical amounts of time to elapse on each clock—just five minutes in a blitz tournament—representing the total time the player can take for all moves in the game. The flag near the twelve on each clock is pushed aside by the black hand as it approaches twelve. When the flag falls, the player has exceeded his allotted time, and so forfeits the match.

That's not to say that all problems are solved by comparing them to cases you've seen in the past. You do, of course, sometimes reason, and even when you do, background knowledge can help. Earlier in this chapter I discussed chunking, the process that allows us to think of individual items as a single unit (for example, when *C*, *N*, and *N* become *CNN*), thereby creating more room in working memory. I emphasized that in reading, the extra mental space afforded by chunking can be used to relate the meaning of sentences to one another. This extra space is also useful when reasoning.

Here's an example. Do you have a friend who can walk into someone else's kitchen and rapidly produce a nice dinner from whatever food is around, usually to the astonishment of whoever's kitchen it is? When your friend looks in a cupboard, she doesn't see ingredients, she see recipes. She draws on extensive background knowledge about food and cooking. For example, have a look at the pantry in Figure 9.

FIGURE 9: Suppose you were at a friend's house and she asked you to make dinner with some chicken and whatever else you could find. What would you do?

A food expert will have the background knowledge to see many recipes here, for example, wild rice cranberry stuffing or chicken with salsa over pasta. The necessary ingredients will then become a chunk in working memory, so the expert will have room in working memory to devote to other aspects of planning, for example, to consider other dishes that might complement this one, or to begin to plan the steps of cooking.

Chunking applies to classroom activities as well. For example, take two algebra students. One is still a little shaky on the distributive property, the other knows it cold. When the first student is trying to solve a problem and sees a(b + c), he's unsure whether that's the same as ab + c, or b + ac, or ab + ac. So he stops working on the problem and substitutes small numbers into a(b + c) to be sure he's got it right. The second student recognizes a(b + c) as a chunk and doesn't need to stop and occupy working memory with this subcomponent of the problem. Clearly the second student is more likely to complete the problem successfully.

There is a final point to be made about knowledge and thinking skills. Much of what experts tell us they do in the course of thinking about their field *requires* background knowledge, even if it's not described that way. Let's take science as an example. We could tell students a lot about how scientists think, and they could memorize those bits of advice. For example, we could tell students that when interpreting the results of an experiment, scientists are especially interested in anomalous (that is, unexpected) outcomes. Unexpected outcomes indicate that their knowledge is incomplete and that this experiment contains hidden seeds of new knowledge. But for results to be unexpected, you must have an expectation! An expectation about the outcome would be based on your knowledge of the field. Most or all of what we tell students about scientific thinking strategies is impossible to use without appropriate background knowledge. (See Figure 10.)

The same holds true for history, language arts, music, and so on. Generalizations that we can offer to students about how to think and reason successfully in the field may *look* like

FIGURE 10: Scientists are good at "thinking like scientists," but doing so depends not just on knowing and practicing the thinking strategies, but also on having background knowledge that allows them to use the thinking strategies. This may be why a well-known geologist, H. H. Read, said, "The best geologist is the one who has seen the most rocks."

they don't require background knowledge, but when you consider how to apply them, they actually do.

Factual Knowledge Improves Your Memory

When it comes to knowledge, those who have more gain more. Many experiments have confirmed the benefit of background knowledge to memory using the same basic method. The researchers bring into the laboratory some people who have some expertise in a field (for example, football or dance or electronic circuitry) and some who do not. Everyone reads a story or a brief article. The material is simple enough that the people without expertise have no difficulty understanding it; that is, they can tell you what each sentence means. But the next day the people with background knowledge remember substantially more of the material than the people who do not have background knowledge.

You might think this effect is really due to attention. If I'm a basketball fan, I'll enjoy reading about basketball and will pay close attention, whereas if I'm not a fan, reading about basketball will bore me. But other studies have actually *created* experts. The researchers had people learn either a lot or just a little about subjects that were new to them (for example, Broadway musicals). Then they had them read other, new facts about the subject, and they found that the "experts" (those who had earlier learned a lot of facts about the subject) learned new facts more quickly and easily than the "novices" (who had earlier learned just a few facts about the subject).[6]

Why is it easier to remember material if you already know something about the topic? I've already said that if you know more about a particular topic, you can better understand new information about that topic; for example, people who know about baseball *understand* a baseball story better than people who don't. We remember much better if something has meaning. That generalization is discussed and refined in the next chapter, but to get a sense of this effect, read each of the following two brief paragraphs:

Motor learning is the change in capacity to perform skilled movements that achieve behavioral goals in the environment. A fundamental and unresolved question in neuroscience is whether there is a separate neural system for representing learned sequential motor responses. Defining that system with brain imaging and other methods requires a careful description of what specifically is being learned for a given sequencing task.

A chiffon cake replaces butter—the traditional fat in cakes—with oil. A fundamental and unresolved question in baking is when to make a butter cake and when to make a chiffon cake. Answering this question with expert tasting panels and other methods requires a careful description of what characteristics are desired for a cake.

The paragraph on the left is taken from a technical research article.[7] Each sentence is likely comprehensible, and if you take your time, you can see how they are connected: The first sentence provides a definition, the second sentence poses a problem, and the third states that a description of the thing under study (skills) is necessary before the problem can be addressed. I wrote the paragraph on the right to parallel the motor-skill paragraph. Sentence by sentence, the structure is the same. Which do you think you will remember better tomorrow?

The paragraph on the right is easier to understand (and therefore will be better remembered) because you can tie it to things you already know. Your experience tells you that a good cake tastes buttery, not oily, so the interest value of the fact that some are made with oil is apparent. Similarly, when the final sentence refers to "what characteristics are desired for a cake," you can imagine what those characteristics might be—fluffiness, moistness, and so on. Note that these effects aren't about comprehension; you can comprehend the paragraph on the left pretty well despite a lack of background knowledge. But some richness, some feeling of depth to the comprehension is missing. That's because when you have background knowledge your mind connects the material you're reading with what you already know about the topic, even if you're not aware that it's happening.

It's those connections that will help you remember the paragraph tomorrow. Remembering things is all about *cues* to memory. We dredge up memories when we think of things that are related to what we're trying to remember. Thus, if I said, "Try to remember that paragraph you read yesterday," you'd say to yourself, "Right, it was about cakes," and automatically (and perhaps outside of awareness) information about cakes would start to flit through your mind—they are baked . . . they are frosted . . . you have them at birthday parties . . . they are made with flour and eggs and butter . . . and suddenly, that background knowledge (that cakes are made with butter) provides a toehold for remembering the paragraph: "Right, it was about a cake that uses oil instead of butter." It's adding these lines from the paragraph to your background knowledge that makes the paragraph seem both better understood and easier to remember. The motor-skills paragraph, alas, is marooned, removed from any background knowledge, and so is more difficult to remember later.

This final effect of background knowledge—that having factual knowledge in long-term memory makes it easier to acquire still more factual knowledge—is worth contemplating for a moment. It means that the amount of information you retain depends on what you already have. So, if you have more than I do, you retain more than I do, which means you gain more than me. To make the idea concrete (but the numbers manageable), suppose you have ten thousand facts in your memory but I have only nine thousand. Let's say we each remember a percentage of new stuff, and that percentage is based on what's already in our memories. You remember 10 percent of the new facts you hear, but because I have less knowledge in long-term memory, I remember only 9 percent of new facts. Table 1 shows how many facts each of us has in long-term memory over the course of ten months, assuming we're each exposed to five hundred new facts each month.

By the end of ten months, the gap between us has widened from 1,000 facts to 1,043 facts. Because people who have more in long-term memory learn more easily, the gap

TABLE 1: A demonstration that, when it comes to knowledge, the rich get richer.

Months	Facts in your memory	% of new facts you remember	Facts in my memory	% of new facts I remember
1	10,000	10.000	9,000	9.000
2	10,050	10.050	9,045	9.045
3	10,100	10.100	9,090	9.090
4	10,151	10.151	9,135	9.135
5	10,202	10.202	9,181	9.181
6	10,253	10.253	9,227	9.227
7	10,304	10.304	9,273	9.273
8	10,356	10.356	9,319	9.319
9	10,408	10.408	9,366	9.366
10	10,460	10.460	9,413	9.413

is only going to get wider. The only way I could catch up is to make sure I am exposed to more facts than you are. In a school context, I have some catching up to do, but it's very difficult because you are pulling away from me at an ever-increasing speed.

I have of course made up all of the numbers in the foregoing example, but we know that the basics are correct—the rich get richer. We also know where the riches lie. If you want to be exposed to new vocabulary and new ideas, the places to go are books, magazines, and newspapers. Television, video games, and the sorts of Internet content that students lean toward (for example, social networking sites, music sites, and the like) are for the most part unhelpful. Researchers have painstakingly analyzed the contents of the many ways that students can spend their leisure time. Books, newspapers, and magazines are singularly helpful in introducing new ideas and new vocabulary to students.

I began this chapter with a quotation from Einstein: "Imagination is more important than knowledge." I hope you are now persuaded that Einstein was wrong. Knowledge is more important, because it's a prerequisite for imagination, or at least for the sort of imagination that leads to problem solving, decision making, and creativity. Other great minds have made similar comments that denigrate the importance of knowledge, as shown in Table 2.

I don't know why some great thinkers (who undoubtedly knew many facts) took delight in denigrating schools, often depicting them as factories for the useless memorization of information. I suppose we are to take these remarks as ironic, or at least as interesting, but I for one don't need brilliant, highly capable minds telling me (and my children) how silly it is to know things. As I've shown in this chapter, the

TABLE 2: Quotations from great thinkers denigrating the importance of factual knowledge.

Education is what survives when what has been learned has been forgotten.	Psychologist B. F. Skinner
I have never let my schooling interfere with my education.	Writer Mark Twain
Nothing in education is so astonishing as the amount of ignorance it accumulates in the form of inert facts.	Writer Henry Brooks Adams
Your learning is useless to you till you have lost your textbooks, burnt your lecture notes, and forgotten the minutiae which you learned by heart for the examination.	Philosopher Alfred North Whitehead
We are shut up in schools and college recitation rooms for ten or fifteen years, and come out at last with a bellyful of words and do not know a thing.	Poet Ralph Waldo Emerson

cognitive processes that are most esteemed—logical thinking, problem solving, and the like—are intertwined with knowledge. It is certainly true that facts without the skills to use them are of little value. It is equally true that one cannot deploy thinking skills effectively without factual knowledge.

As an alternative to the quotations in Table 2, I offer a Spanish proverb that emphasizes the importance of experience and, by inference, knowledge: *Mas sabe El Diablo por viejo que por Diablo.* Roughly translated: "The Devil is not wise because he's the Devil. The Devil is wise because he's *old.*"

Implications for the Classroom

If factual knowledge makes cognitive processes work better, the obvious implication is that we must help children learn background knowledge. How can we ensure that that happens?

How to Evaluate Which Knowledge to Instill

We might well ask ourselves, *Which knowledge should students be taught?* This question often becomes politically charged rather quickly. When we start to specify what must be taught and what can be omitted, it appears that we are grading information on its importance. The inclusion or omission of historical events and figures, playwrights, scientific achievements, and so on, leads to charges of cultural bias. A cognitive scientist sees these issues differently. The question, *What should students be taught?* is equivalent not to *What knowledge is important?* but rather to *What knowledge yields the greatest cognitive benefit?* This question has two answers.

For reading, students must know whatever information writers assume they know and hence leave out. The necessary knowledge will vary depending on what students read, but most observers would agree that a reasonable minimum target would be to read a daily newspaper and to read books written for the intelligent layman on serious topics such as science and politics. Using that criterion, we may still be distressed that much of what writers assume their readers know seems to be touchstones of the culture of dead white males. From the cognitive scientist's point of view, the only choice in that case is to try to persuade writers and editors at the *Washington Post, Chicago Tribune*, and so on to assume different knowledge on the part of their readers. I don't think anyone would claim that change would be easy to bring about. It really amounts to a change in culture. Unless and until that happens, I advocate teaching that material to our students. The simple fact is that without that knowledge, they cannot read the breadth of material that their more knowledgeable schoolmates can, nor with the depth of comprehension.

The second answer to the question applies to core subject matter courses. *What should students know of science, of history, of mathematics?* This question is different than the first because the uses of knowledge in these subject areas are different than the uses of knowledge for general reading. Reading requires relatively shallow knowledge. I don't need to know much about a nebula to understand the word when it's used in a newspaper article; but if I'm studying astrophysics, I need to know much more.

Students can't learn everything, so what should they know? Cognitive science leads to the rather obvious conclusion that students must learn the concepts that come up again and again—the unifying ideas of each discipline. Some educational thinkers have suggested that a limited number of ideas should be taught in great depth, beginning in the early grades and carrying through the curriculum for years as different topics are taken up and viewed through the lens of one or more of these ideas. From the cognitive perspective, that makes sense.

Be Sure That the Knowledge Base Is Mostly in Place When You Require Critical Thinking

Our goal is not simply to have students know a lot of stuff—it's to have them know stuff in service of being able to think effectively. As emphasized in this chapter, thinking critically requires background knowledge. Critical thinking is not a set of procedures that can be practiced and perfected while divorced from background knowledge. Thus it makes sense to consider whether students have the necessary background knowledge to carry out a critical thinking task you might assign. For example, I once observed a teacher ask her fourth-grade class what they thought it would be like to live in a rain forest. Although the students had spent a couple of days talking about rain forests, they didn't have the background knowledge to give anything beyond rather shallow responses (such as "It would be rainy"). She asked the same question at the end of the unit, and the student's answers were much richer. One student immediately said she wouldn't want to live there because the poor soil and constant shade would mean she would probably have to include meat in her diet—and she was a vegetarian.

Shallow Knowledge Is Better Than No Knowledge

Some of the benefits of factual knowledge require that the knowledge be fairly deep—for example, we need detailed knowledge to be able to chunk. But other benefits accrue from shallow knowledge. As has been noted, we usually do not need to have detailed knowledge of a concept to be able to understand its meaning in context when we're reading. For example, I know almost nothing about baseball, but for general reading, a shallow definition such as "a sport played with a bat and ball, in which two teams oppose one another" will often do. Of course deep knowledge is better than shallow knowledge. But we're not going to have deep knowledge of everything, and shallow knowledge is certainly better than no knowledge.

Do Whatever You Can to Get Kids to Read

The effects of knowledge described in this chapter also highlight why reading is so important. Books expose children to more facts and to a broader vocabulary than virtually any other activity, and persuasive data indicate that people who read for pleasure enjoy cognitive benefits throughout their lifetime. I don't believe it is quite the case that any book is fine "as long as they're reading." Naturally, if a child has a history of resisting reading, I'd be happy if she picked up any book at all. But once she is over that hump, I'd start trying to nudge her toward books at the appropriate reading level. It's rather obvious that a student doesn't gain much from reading books several grades below her reading level. I'm all for reading for pleasure, but there are fun, fascinating books at every reading level, so why not encourage age-appropriate materials? It's just as obvious that a too difficult book is a bad idea. The student won't understand it and will just end up frustrated. The school librarian should be a tremendous resource and ally in helping children learn to love reading, and she is arguably the most important person in any school when it comes to reading.

Knowledge Acquisition Can Be Incidental

The learning of factual knowledge can be incidental—that is, it can happen simply by exposure rather than only by concentrated study or memorization. Think about all you have learned by reading books and magazines for pleasure, or by watching documentaries and the news on television, or through conversation with friends. School offers many of the same opportunities. Students can learn information from math problems, or through sample sentences when they are learning grammar, or from the vocabulary you use when you select a classroom monitor. Every teacher knows so much that students don't. There are opportunities to fold this knowledge into each school day.

Start Early

At the end of the last section I noted that a child who starts behind in terms of knowledge will fall even farther behind unless there is some intervention. There seems to be little doubt that this is a major factor in why some children fare poorly in school. Home environments vary a great deal. What sort of vocabulary do parents use? Do the parents ask the children questions and listen to the children's answers? Do they take their child to the museum or aquarium? Do they make books available to their children? Do the children observe their parents reading? All of these factors (and others) likely play a role in what children know on their first day of school. In other words, before a child meets her first teacher, she may be quite far behind the child sitting next to her in terms of how easy it is going to be for her to learn. Trying to level this playing field is a teacher's greatest challenge. There are no shortcuts and no alternatives to trying to increase the factual knowledge that the child has not picked up at home.

Knowledge Must Be Meaningful

Teachers should not take the importance of knowledge to mean that they should create lists of facts—whether shallow or detailed—for students to learn. Sure, some benefit might accrue, but it would be small. Knowledge pays off when it is conceptual and when the facts are related to one another, and that is not true of list learning. Also, as any teacher knows, such drilling would do far more harm by making students miserable and by encouraging the belief that school is a place of boredom and drudgery, not excitement and discovery. Most teachers also know that learning lists of unconnected facts is pretty hard to do. But what is a better way to ensure that students acquire factual knowledge, now that we've concluded it's so important? In other words, why do some things stick in our memory whereas other things slip away? That is the topic of the next chapter.

Notes

* One of the pleasures of the experiences shared with a close friend is the "inside joke," a reference that only the two of you understand. Hence, if her best friend asked what she was doing, the typist might say, "I'm painting a gravel road"—their personal code, based on a shared experience, for a long, pointless task. That's one extreme of assuming information on the part of your audience.

† Tournament-level chess players all have rankings—a number representing their skill level—based on whom they have beaten and who has beaten them.

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