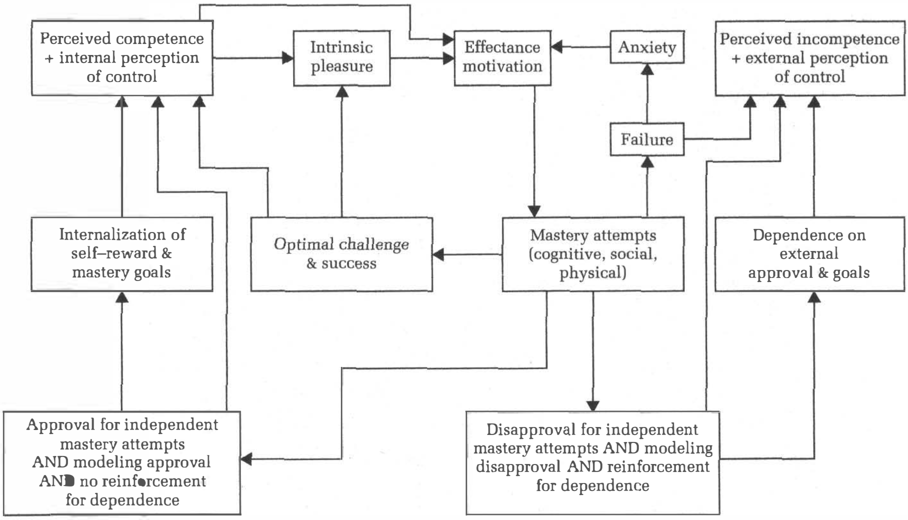

FIGURE 5: A difficult-to-understand figure that will bore most people unless it is adequately introduced.

To summarize, I've said that thinking is slow, effortful, and uncertain. Nevertheless, people like to think—or more properly, we like to think if we judge that the mental work will pay off with the pleasurable feeling we get when we solve a problem. So there is no inconsistency in claiming that people avoid thought and in claiming that people are naturally curious—curiosity prompts people to explore new ideas and problems, but when we do, we quickly evaluate how much mental work it will take to solve the problem. If it's too much or too little, we stop working on the problem if we can.

This analysis of the sorts of mental work that people seek out or avoid also provides one answer to why more students don't like school. Working on problems that are of the right level of difficulty is rewarding, but working on problems that are too easy or too difficult is unpleasant. Students can't opt out of these problems the way adults often can. If the student routinely gets work that is a bit too difficult, it's little wonder that he doesn't care much for school. I wouldn't want to work on the Sunday *New York Times* crossword puzzle for several hours each day.

So what's the solution? Give the student easier work? You could, but of course you'd have to be careful not to make it so easy that the student would be bored. And anyway, wouldn't it be better to boost the student's ability a little bit? Instead of making the work easier, is it possible to make thinking easier?

How Thinking Works

Understanding a bit about how thinking happens will help you understand what makes thinking hard. That will in turn help you understand how to make thinking easier for your students, and therefore help them enjoy school more.

Let's begin with a very simple model of the mind. On the left of Figure 6 is the environment, full of things to see and hear, problems to be solved, and so on. On the right is one component of your mind that scientists call *working memory.* For the moment, consider it to be synonymous with consciousness; it holds the stuff you're thinking about. The arrow from the environment to working memory shows that working memory is the part of your mind where you are aware of what is around you: the sight of a shaft of light falling onto a dusty table, the sound of a dog barking in the distance, and so forth. Of course you can also be aware of things that are not currently in the environment; for example, you can recall the sound of your mother's voice, even if she's not in the room (or indeed no longer living). *Long-term memory* is the vast storehouse in which you maintain your factual knowledge of the world: that ladybugs have spots, that your favorite flavor of ice cream is chocolate, that your three-year-old surprised you yesterday by mentioning kumquats, and so on. Factual knowledge can be abstract; for example, it would include the idea that triangles are closed figures with three sides, and your knowledge of what a dog generally looks like. All of the information in long-term memory resides outside of awareness. It lies quietly until it is needed, and then enters working memory and so becomes conscious. For example, if I asked you, "What color is a polar bear?" you would say, "white" almost immediately. That information was in long-term memory thirty second ago, but you weren't aware of it until I posed the question that made it relevant to ongoing thought, whereupon it entered working memory.

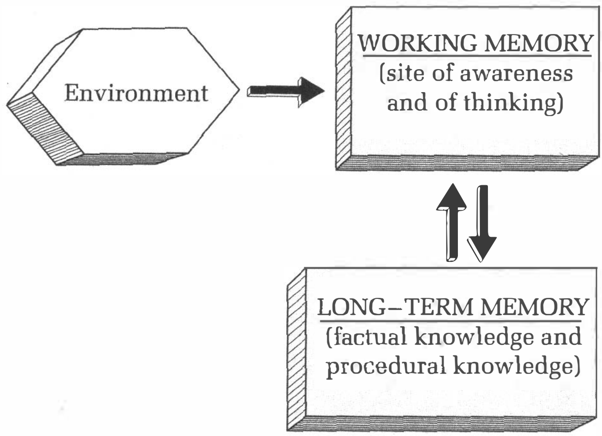

FIGURE 6: Just about the simplest model of the mind possible.

Thinking occurs when you combine information (from the environment and long-term memory) in new ways. That combining happens in working memory. To get a feel for this process, read the problem depicted in Figure 7 and try to solve it. (The point is not so much to solve it as to experience what is meant by thinking and working memory.)

With some diligence you might be able to solve this problem,† but the real point is to feel what it's like to have working memory absorbed by the problem. You begin by taking information from the environment—the rules and the configuration of the game board—and then imagine moving the discs to try to reach the goal. Within working memory you must maintain your current state in the puzzle—where the discs are—and imagine and evaluate potential moves. At the same time you have to remember the rules regarding which moves are legal, as shown in Figure 8.

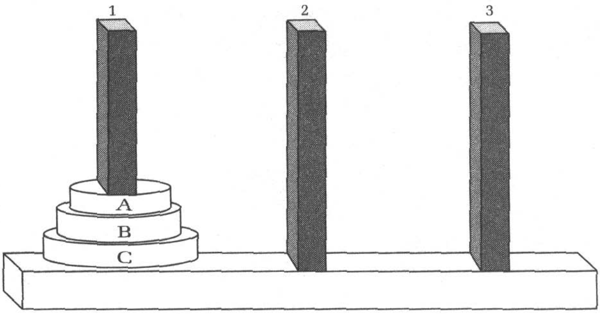

FIGURE 7: The figure depicts a playing board with three pegs. There are three rings of decreasing size on the leftmost peg. The goal is to move all three rings from the leftmost peg to the rightmost peg. There are just two rules about how you can move rings: you can move only one ring at a time, and you can't place a larger ring on top of a smaller ring.

The description of thinking makes it clear that knowing *how* to combine and rearrange ideas in working memory is essential to successful thinking. For example, in the discs and pegs problem, how do you know where to move the discs? If you hadn't seen the problem before, you probably felt like you were pretty much guessing. You didn't have any information in long-term memory to guide you, as depicted in Figure 8. But if you have had experience with this particular type of problem, then you likely have information in long-term memory about how to solve it, even if the information is not foolproof. For example, try to work this math problem in your head:

$$18 \times 7$$

You know just what to do for this problem. I'm confident that the sequence of your mental processes was something close to this:

1. Multiple 8 and 7.
2. Retrieve the fact that $8 \times 7 = 56$ from long-term memory.
3. Remember that the 6 is part of the solution, then carry the 5.
4. Multiply 7 and 1.
5. Retrieve the fact that $7 \times 1 = 7$ from long-term memory.
6. Add the carried 5 to the 7.
7. Retrieve the fact that $5 + 7 = 12$ from long-term memory.
8. Put the 12 down, append the 6.
9. The answer is 126.

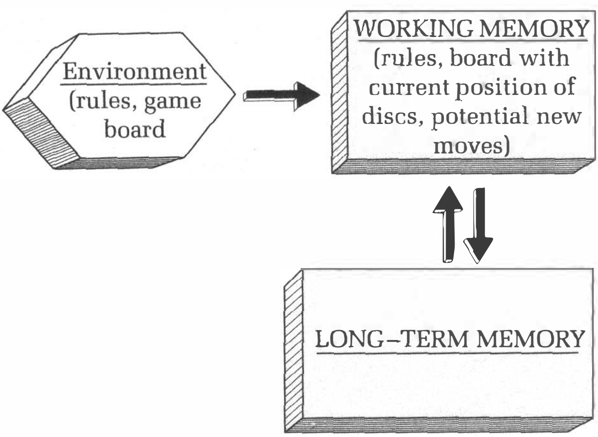

FIGURE 8: A depiction of your mind when you're working on the puzzle shown in Figure 7.

Your long-term memory contains not only factual information, such as the color of polar bears and the value of 8×7, but it also contains what we'll call *procedural knowledge*, which is your knowledge of the mental procedures necessary to execute tasks. If thinking is combining information in working memory, then procedural knowledge is a list of what to combine and when—it's like a recipe to accomplish a particular type of thought. You might have stored procedures for the steps needed to calculate the area of a triangle, or to duplicate a computer file using Windows, or to drive from your home to your office.

It's pretty obvious that having the appropriate procedure stored in long-term memory helps a great deal when we're thinking. That's why it was easy to solve the math problem and hard to solve the discs-and-pegs problem. But how about factual knowledge? Does that help you think as well? It does, in several different ways, which are discussed in Chapter Two. For now, note that solving the math problem required the retrieval of factual information, such as the fact that $8 \times 7 = 56$. I've said that thinking entails combining information in working memory. Often the information provided in the environment is not sufficient to solve a problem, and you need to supplement it with information from long-term memory.

There's a final necessity for thinking, which is best understood through an example. Have a look at this problem:

In the inns of certain Himalayan villages is practiced a refined tea ceremony. The ceremony involves a host and exactly two guests, neither more nor less. When his guests have arrived and seated themselves at his table, the host performs three services for them. These services are listed in the order of the nobility the Himalayans attribute to them: stoking the fire, fanning the flames, and pouring the tea. During the ceremony, any of those present may ask another, "Honored Sir, may I perform this onerous task for you?" However, a person may request of another only the least noble of the tasks which the other is performing. Furthermore, if a person is performing any tasks, then he may not request a task that is nobler than the least noble task he is already performing. Custom requires that by the time the tea ceremony is over, all the tasks will have been transferred from the host to the most senior of the guests. How can this be accomplished?[3]

Your first thought upon reading this problem was likely "Huh?" You could probably tell that you'd have to read it several times just to understand it, let alone begin

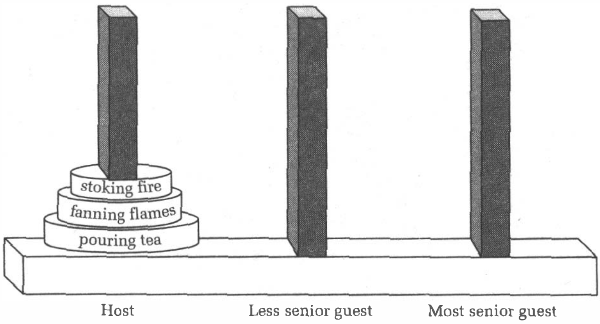

FIGURE 9: The tea-ceremony problem, depicted to show the analogy to the discs-and-pegs problem.

working on the solution. It seemed overwhelming because you did not have sufficient space in working memory to hold all of the aspects of the problem. Working memory has limited space, so thinking becomes increasingly difficult as working memory gets crowded.

The tea-ceremony problem is actually the same as the discs-and-pegs problem presented in Figure 7. The host and two guests are like the three pegs, and the tasks are the three discs to be moved among them, as shown in Figure 9. (The fact that very few people see this analogy and its importance for education is taken up in Chapter Four.)

This version of the problem seems much harder because some parts of the problem that are laid out in Figure 7 must be juggled in your head in this new version. For example, Figure 7 provides a picture of the pegs you can use to help maintain a mental image of the discs as you consider moves. The rules of the problem occupy so much space in working memory that it's difficult to contemplate moves that might lead to a solution.

In sum, successful thinking relies on four factors: information from the environment, facts in long-term memory, procedures in long-term memory, and the amount of space in working memory. If any one of these factors is inadequate, thinking will likely fail.

Let me summarize what I've said in this chapter. People's minds are not especially well-suited to thinking; thinking is slow, effortful, and uncertain. For this reason, deliberate thinking does not guide people's behavior in most situations. Rather, we rely on our memories, following courses of action that we have taken before. Nevertheless, we find *successful* thinking pleasurable. We like solving problems, understanding new ideas, and so forth. Thus, we will seek out opportunities to think, but we are selective in doing so; we choose problems that pose some challenge but that seem likely to be solvable, because these are the problems that lead to feelings of pleasure and satisfaction. For problems to be solved, the thinker needs adequate information from the environment, room in working memory, and the required facts and procedures in long-term memory.

Implications for the Classroom

Let's turn now to the question that opened this chapter: Why don't students like school, or perhaps more realistically, why don't more of them like it? Any teacher knows that