1

Why Don't Students Like School?

Question: Most of the teachers I know entered the profession because they loved school as children. They want to help their students feel the same excitement and passion for learning that they felt. They are understandably dejected when they find that some of their pupils don't like school much, and that they, the teachers, have great difficulty inspiring them. Why is it difficult to make school enjoyable for students?

Answer: Contrary to popular belief, the brain is not designed for thinking. It's designed to save you from having to think, because the brain is actually not very good at thinking. Thinking is slow and unreliable. Nevertheless, people enjoy mental work if it is successful. People like to solve problems, but not to work on unsolvable problems. If schoolwork is always just a bit too difficult for a student, it should be no surprise that she doesn't like school much. The cognitive principle that guides this chapter is:

> People are naturally curious, but we are not naturally good thinkers; unless the cognitive conditions are right, we will avoid thinking.

The implication of this principle is that teachers should reconsider how they encourage their students to think, in order to maximize the likelihood that students will get the pleasurable rush that comes from successful thought.

The Mind Is Not Designed for Thinking

What is the essence of being human? What sets us apart from other species? Many people would answer that it is our ability to reason—birds fly, fish swim, and humans think. (By *thinking* I mean solving problems, reasoning, reading something complex, or doing any mental work that requires some effort.) Shakespeare extolled our cognitive ability in *Hamlet*: "What a piece of work is man! How noble in reason!" Some three hundred years later, however, Henry Ford more cynically observed, "Thinking is the hardest work there is, which is the probable reason why so few people engage in it."* They both had a point. Humans are good at certain types of reasoning, particularly in comparison to other animals, but we exercise those abilities infrequently. A cognitive scientist would add another observation: Humans don't think very often because our brains are designed not for thought but for the avoidance of thought. Thinking is not only effortful, as Ford noted, it's also slow and unreliable.

Your brain serves many purposes, and thinking is not the one it serves best. Your brain also supports the ability to see and to move, for example, and these functions operate much more efficiently and reliably than your ability to think. It's no accident that most of your brain's real estate is devoted to these activities. The extra brain power is needed because seeing is actually more difficult than playing chess or solving calculus problems.

You can appreciate the power of your visual system by comparing human abilities to those of computers. When it comes to math, science, and other traditional "thinking" tasks, machines beat people, no contest. Five dollars will get you a calculator that can perform simple calculations faster and more accurately than any human can. With fifty dollars you can buy chess software that can defeat more than 99 percent of the world's population. But the most powerful computer on the planet can't drive a truck. That's because computers can't see, especially not in complex, ever-changing environments like the one you face every time you drive. Robots are similarly limited in how they move. Humans are excellent at configuring our bodies as needed for tasks, even if the configuration is unusual, such as when you twist your torso and contort your arm in an effort to dust behind books on a shelf. Robots are not very good at figuring out novel ways to move, so they are useful mostly for repetitive work such as spray painting automotive parts, for which the required movements are always the same. Tasks that you take for granted—for example, walking on a rocky shore where the footing is uncertain—are much more difficult than playing top-level chess. No computer can do it (Figure 1).

Compared to your ability to see and move, thinking is slow, effortful, and uncertain. To get a feel for why I say this, try solving this problem:

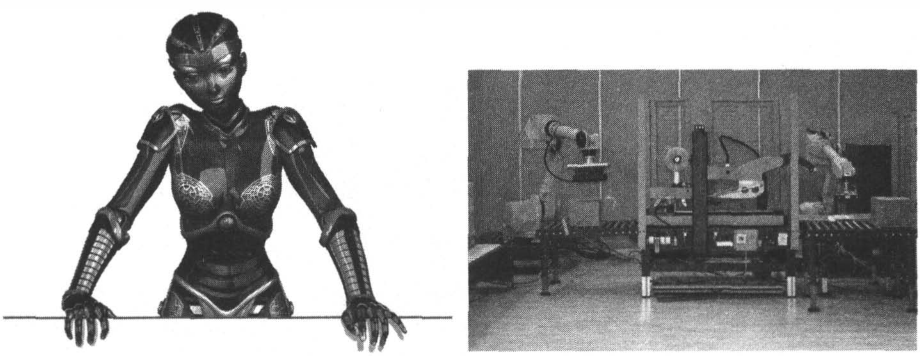


FIGURE 1: Hollywood robots (left), like humans, can move in complex environments, but that's true only in the movies. Most real-life robots (right) move in predictable environments. Our ability to see and move is a remarkable cognitive feat.

In an empty room are a candle, some matches, and a box of tacks. The goal is to have the lit candle about five feet off the ground. You've tried melting some of the wax on the bottom of the candle and sticking it to the wall, but that wasn't effective. How can you get the lit candle five feet off the ground without having to hold it there?[1]

Twenty minutes is the usual maximum time allowed, and few people are able to solve it by then, although once you hear the answer you will realize it's not especially tricky. You dump the tacks out of the box, tack the box to the wall, and use it as a platform for the candle.

This problem illustrates three properties of thinking. First, thinking is *slow.* Your visual system instantly takes in a complex scene. When you enter a friend's backyard you don't think to yourself, "Hmmm, there's some green stuff. Probably grass, but it could be some other ground cover—and what's that rough brown object sticking up there? A fence, perhaps?" You take in the whole scene—lawn, fence, flowerbeds, gazebo—at a glance. Your thinking system does not instantly calculate the answer to a problem the way your visual system immediately takes in a visual scene. Second, thinking is *effortful;* you don't have to try to see, but thinking takes concentration. You can perform other tasks while you are seeing, but you can't think about something else while you are working on a problem. Finally, thinking is *uncertain.* Your visual system seldom makes mistakes, and when it does you usually think you see something similar to what is actually out there—you're close, if not exactly right. Your thinking system might not even get you close; your solution to a problem may be far from correct. In fact, your thinking system may not produce an answer at all, which is what happens to most people when they try to solve the candle problem.

If we're all so bad at thinking, how does anyone get through the day? How do we find our way to work or spot a bargain at the grocery store? How does a teacher make the hundreds of decisions necessary to get through her day? The answer is that when we can get away with it, we don't think. Instead we rely on memory. Most of the problems we face are ones we've solved before, so we just do what we've done in the past. For example, suppose that next week a friend gives you the candle problem. You immediately say, "Oh, right. I've heard this one. You tack the box to the wall." Just as your visual system takes in a scene and, without any effort on your part, tells you what is in the environment, so too your memory system immediately and effortlessly recognizes that you've heard the problem before and provides the answer. You may think you have a terrible memory, and it's true that your memory system is not as reliable as your visual or movement system—sometimes you forget, sometimes you *think* you remember when you don't—but your memory system is much more reliable than your thinking system, and it provides answers quickly and with little effort.

We normally think of memory as storing personal events (memories of my wedding) and facts (George Washington was the first president of the United States).

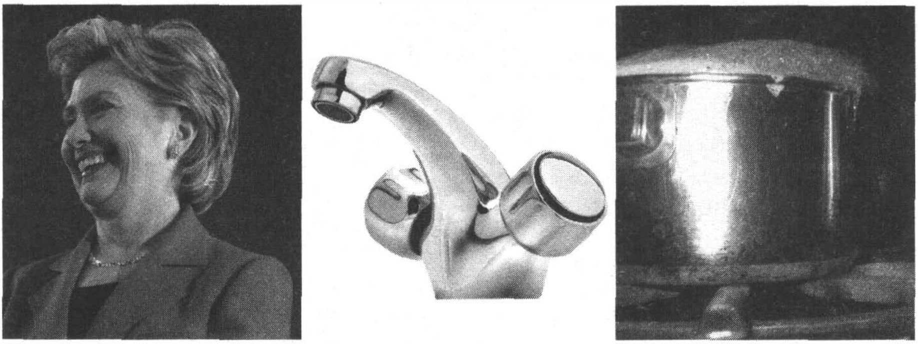


FIGURE 2: Your memory system operates so quickly and effortlessly that you seldom notice it working. For example, your memory has stored away information about what things look like (Hillary Clinton's face) and how to manipulate objects (turn the left faucet for hot water, the right for cold), and strategies for dealing with problems you've encountered before (such as a pot boiling over).

Our memory also stores strategies to guide what we should do: where to turn when driving home, how to handle a minor dispute when monitoring recess, what to do when a pot on the stove starts to boil over (Figure 2). For the vast majority of decisions we make, we don't stop to consider what we might do, reason about it, anticipate possible consequences, and so on. For example, when I decide to make spaghetti for dinner, I don't pore over my cookbooks, weighing each recipe for taste, nutritional value, ease of preparation, cost of ingredients, visual appeal, and so on—I just make spaghetti sauce the way I usually do. As two psychologists put it, "Most of the time what we do is what we do most of the time."[2] When you feel as though you are "on autopilot," even if you're doing something rather complex, such as driving home from school, it's because you are using memory to guide your behavior. Using memory doesn't require much of your attention, so you are free to daydream, even as you're stopping at red lights, passing cars, watching for pedestrians, and so on.

Of course you *could* make each decision with care and thought. When someone encourages you to "think outside the box" that's usually what he means—don't go on autopilot, don't do what you (or others) have always done. Consider what life would be like if you *always* strove to think outside the box. Suppose you approached every task afresh and tried to see all of its possibilities, even daily tasks like chopping an onion, entering your office building, or buying a soft drink at lunch. The novelty might be fun for a while, but life would soon be exhausting (Figure 3).

You may have experienced something similar when traveling, especially if you've traveled where you don't speak the local language. Everything is unfamiliar and even trivial actions demand lots of thought. For example, buying a soda from a vendor requires figuring out the flavors from the exotic packaging, trying to communicate with the vendor, working through which coin or bill to use, and so on. That's one reason that traveling is so tiring: all of the trivial actions that at home could be made on autopilot require your full attention.

So far I've described two ways in which your brain is set up to save you from having to think. First, some of the most important functions (for example, vision and movement) don't require thought: you don't have to reason about what you see; you just immediately know what's out in the world. Second, you are biased to use memory to guide your actions rather than to think. But your brain doesn't leave it there; it is capable of changing in order to save you from having to think. If you repeat the same thought-demanding task again and again, it will eventually become automatic; your brain will change so that you can complete the task without thinking about it. I discuss this process in more detail in Chapter Five, but a familiar example here will illustrate what I mean. You can probably recall that learning to drive a car was mentally very demanding. I remember focusing on how hard to depress the accelerator, when and how to apply the brake as I approached a red light, how far to turn the steering wheel to execute a turn, when to check my mirrors, and so forth. I didn't even listen to the radio while I drove, for fear of being distracted. With practice, however, the process of driving became automatic, and now I don't need to think about those small-scale bits of driving any more than I need to think about how to walk. I can drive while simultaneously chatting with friends, gesturing with one hand, and eating French fries—an impressive cognitive feat, if not very attractive to watch. Thus a task that initially takes a great deal of thought becomes, with practice, a task that requires little or no thought.

FIGURE 3: "Thinking outside the box" for a mundane task like selecting bread at the supermarket would probably not be worth the mental effort.

The implications for education sound rather grim. If people are bad at thinking and try to avoid it, what does that say about students' attitudes toward school? Fortunately, the story doesn't end with people stubbornly refusing to think. Despite the fact that we're not that good at it, we actually *like* to think. We are naturally curious, and we look for opportunities to engage in certain types of thought. But because thinking is so hard, the conditions have to be right for this curiosity to thrive, or we quit thinking rather readily. The next section explains when we like to think and when we don't.

People Are Naturally Curious, but Curiosity Is Fragile

Even though the brain is not set up for very efficient thinking, people actually enjoy mental activity, at least in some circumstances. We have hobbies like solving crossword puzzles or scrutinizing maps. We watch information-packed documentaries. We pursue careers—such as teaching—that offer greater mental challenge than competing careers, even if the pay is lower. Not only are we willing to think, we intentionally seek out situations that demand thought.

Solving problems brings pleasure. When I say "problem solving" in this book, I mean any cognitive work that succeeds; it might be understanding a difficult passage of prose, planning a garden, or sizing up an investment opportunity. There is a sense of satisfaction, of fulfillment, in successful thinking. In the last ten years neuroscientists have discovered that there is overlap between the brain areas and chemicals that are important in learning and those that are important in the brain's natural reward system. Many neuroscientists suspect that the two systems are related. Rats in a maze learn better when rewarded with cheese. When you solve a problem, your brain may reward itself with a small dose of dopamine, a naturally occurring chemical that is important to the brain's pleasure system. Neuroscientists know that dopamine is important in both systems—learning and pleasure—but haven't yet worked out the explicit tie between them. Even though the neurochemistry is not completely understood, it seems undeniable that people take pleasure in solving problems.

It's notable too that the pleasure is in the *solving* of the problem. Working on a problem with no sense that you're making progress is not pleasurable. In fact, it's frustrating. Then too, there's not great pleasure in simply knowing the answer. I told you the solution to the candle problem; did you get any fun out of it? Think how much more fun it would have been if you had solved it yourself—in fact, the problem would have seemed more clever, just as a joke that you get is funnier than a joke that has to be explained. Even if someone doesn't tell you the answer to a problem, once you've had too many hints you lose the sense that *you've* solved the problem, and getting the answer doesn't bring the same mental snap of satisfaction.

Mental work appeals to us because it offers the opportunity for that pleasant feeling when it succeeds. But not all types of thinking are equally attractive. People choose to work crossword puzzles but not algebra problems. A biography of Bono is more likely to sell well than a biography of Keats. What characterizes the mental activity that people enjoy (Figure 4)?

The answer that most people would give may seem obvious: "I think crossword puzzles are fun and Bono is cool, but math is boring and so is Keats." In other words, it's the content that matters. We're curious about some stuff but not about other stuff. Certainly that's the way people describe our own interests—"I'm a stamp collector" or "I'm into medieval symphonic music." But I don't think content drives interest. We've all attended a lecture or watched a TV show (perhaps against our will) about a subject we thought we weren't interested in, only to find ourselves fascinated; and it's easy to get bored even when you usually like the topic. I'll never forget my eagerness for the day my middle school teacher was to talk about sex. As a teenage boy in a staid 1970s suburban culture, I fizzed with anticipation of any talk about sex, anytime, anywhere. But when the big day came, my friends and I were absolutely disabled with boredom. It's not that the teacher talked about flowers and pollination—he really did talk about human sexuality—but somehow it was still dull. I actually wish I could remember how he did it; boring a bunch of hormonal teenagers with a sex talk is quite a feat.

> In an empty room are a candle, some matches, and a box of tacks. The goal is to have the lit candle about five feet off the ground. You've tried melting some of the wax on the bottom of the candle and sticking it to the wall, but that wasn't effective. How can you get the lit candle five feet off the ground without having to hold it there?[1]

Twenty minutes is the usual maximum time allowed, and few people are able to solve it by then, although once you hear the answer you will realize it's not especially tricky. You dump the tacks out of the box, tack the box to the wall, and use it as a platform for the candle.

This problem illustrates three properties of thinking. First, thinking is *slow*. Your visual system instantly takes in a complex scene. When you enter a friend's backyard you don't think to yourself, "Hmmm, there's some green stuff. Probably grass, but it could be some other ground cover—and what's that rough brown object sticking up there? A fence, perhaps?" You take in the whole scene—lawn, fence, flowerbeds, gazebo—at a glance. Your thinking system does not instantly calculate the answer to a problem the way your visual system immediately takes in a visual scene. Second, thinking is *effortful;* you don't have to try to see, but thinking takes concentration. You can perform other tasks while you are seeing, but you can't think about something else while you are working on a problem. Finally, thinking is *uncertain*. Your visual system seldom makes mistakes, and when it does you usually think you see something similar to what is actually out there—you're close, if not exactly right. Your thinking system might not even get you close; your solution to a problem may be far from correct. In fact, your thinking system may not produce an answer at all, which is what happens to most people when they try to solve the candle problem.

If we're all so bad at thinking, how does anyone get through the day? How do we find our way to work or spot a bargain at the grocery store? How does a teacher make the hundreds of decisions necessary to get through her day? The answer is that when we can get away with it, we don't think. Instead we rely on memory. Most of the problems we face are ones we've solved before, so we just do what we've done in the past. For example, suppose that next week a friend gives you the candle problem. You immediately say, "Oh, right. I've heard this one. You tack the box to the wall." Just as your visual system takes in a scene and, without any effort on your part, tells you what is in the environment, so too your memory system immediately and effortlessly recognizes that you've heard the problem before and provides the answer. You may think you have a terrible memory, and it's true that your memory system is not as reliable as your visual or movement system—sometimes you forget, sometimes you *think* you remember when you don't—but your memory system is much more reliable than your thinking system, and it provides answers quickly and with little effort.

We normally think of memory as storing personal events (memories of my wedding) and facts (George Washington was the first president of the United States).

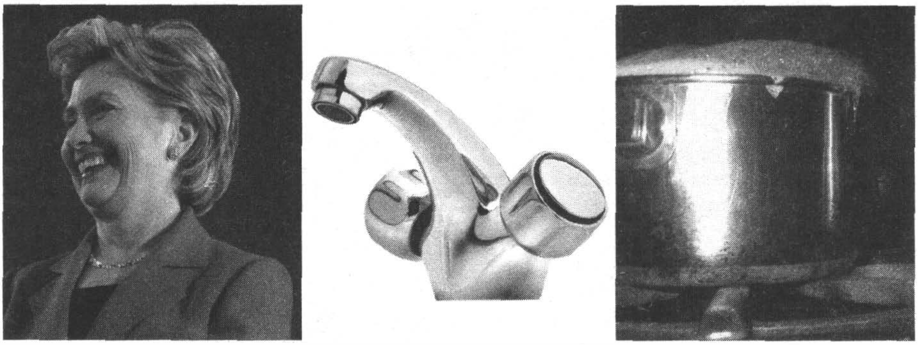


FIGURE 2: Your memory system operates so quickly and effortlessly that you seldom notice it working. For example, your memory has stored away information about what things look like (Hillary Clinton's face) and how to manipulate objects (turn the left faucet for hot water, the right for cold), and strategies for dealing with problems you've encountered before (such as a pot boiling over).

Our memory also stores strategies to guide what we should do: where to turn when driving home, how to handle a minor dispute when monitoring recess, what to do when a pot on the stove starts to boil over (Figure 2). For the vast majority of decisions we make, we don't stop to consider what we might do, reason about it, anticipate possible consequences, and so on. For example, when I decide to make spaghetti for dinner, I don't pore over my cookbooks, weighing each recipe for taste, nutritional value, ease of preparation, cost of ingredients, visual appeal, and so on—I just make spaghetti sauce the way I usually do. As two psychologists put it, "Most of the time what we do is what we do most of the time."[2] When you feel as though you are "on autopilot," even if you're doing something rather complex, such as driving home from school, it's because you are using memory to guide your behavior. Using memory doesn't require much of your attention, so you are free to daydream, even as you're stopping at red lights, passing cars, watching for pedestrians, and so on.

Of course you *could* make each decision with care and thought. When someone encourages you to "think outside the box" that's usually what he means—don't go on autopilot, don't do what you (or others) have always done. Consider what life would be like if you *always* strove to think outside the box. Suppose you approached every task afresh and tried to see all of its possibilities, even daily tasks like chopping an onion, entering your office building, or buying a soft drink at lunch. The novelty might be fun for a while, but life would soon be exhausting (Figure 3).

You may have experienced something similar when traveling, especially if you've traveled where you don't speak the local language. Everything is unfamiliar and even trivial actions demand lots of thought. For example, buying a soda from a vendor requires figuring out the flavors from the exotic packaging, trying to communicate with the vendor, working through which coin or bill to use, and so on. That's one reason that traveling is so tiring: all of the trivial actions that at home could be made on autopilot require your full attention.

FIGURE 3: "Thinking outside the box" for a mundane task like selecting bread at the supermarket would probably not be worth the mental effort.

So far I've described two ways in which your brain is set up to save you from having to think. First, some of the most important functions (for example, vision and movement) don't require thought: you don't have to reason about what you see; you just immediately know what's out in the world. Second, you are biased to use memory to guide your actions rather than to think. But your brain doesn't leave it there; it is capable of changing in order to save you from having to think. If you repeat the same thought-demanding task again and again, it will eventually become automatic; your brain will change so that you can complete the task without thinking about it. I discuss this process in more detail in Chapter Five, but a familiar example here will illustrate what I mean. You can probably recall that learning to drive a car was mentally very demanding. I remember focusing on how hard to depress the accelerator, when and how to apply the brake as I approached a red light, how far to turn the steering wheel to execute a turn, when to check my mirrors, and so forth. I didn't even listen to the radio while I drove, for fear of being distracted. With practice, however, the process of driving became automatic, and now I don't need to think about those small-scale bits of driving any more than I need to think about how to walk. I can drive while simultaneously chatting with friends, gesturing with one hand, and eating French fries—an impressive cognitive feat, if not very attractive to watch. Thus a task that initially takes a great deal of thought becomes, with practice, a task that requires little or no thought.

The implications for education sound rather grim. If people are bad at thinking and try to avoid it, what does that say about students' attitudes toward school? Fortunately, the story doesn't end with people stubbornly refusing to think. Despite the fact that we're not that good at it, we actually *like* to think. We are naturally curious, and we look for opportunities to engage in certain types of thought. But because thinking is so hard, the conditions have to be right for this curiosity to thrive, or we quit thinking rather readily. The next section explains when we like to think and when we don't.

People Are Naturally Curious, but Curiosity Is Fragile

Even though the brain is not set up for very efficient thinking, people actually enjoy mental activity, at least in some circumstances. We have hobbies like solving crossword puzzles or scrutinizing maps. We watch information-packed documentaries. We pursue careers—such as teaching—that offer greater mental challenge than competing careers, even if the pay is lower. Not only are we willing to think, we intentionally seek out situations that demand thought.

Solving problems brings pleasure. When I say "problem solving" in this book, I mean any cognitive work that succeeds; it might be understanding a difficult passage of prose, planning a garden, or sizing up an investment opportunity. There is a sense of satisfaction, of fulfillment, in successful thinking. In the last ten years neuroscientists have discovered that there is overlap between the brain areas and chemicals that are important in learning and those that are important in the brain's natural reward system. Many neuroscientists suspect that the two systems are related. Rats in a maze learn better when rewarded with cheese. When you solve a problem, your brain may reward itself with a small dose of dopamine, a naturally occurring chemical that is important to the brain's pleasure system. Neuroscientists know that dopamine is important in both systems—learning and pleasure—but haven't yet worked out the explicit tie between them. Even though the neurochemistry is not completely understood, it seems undeniable that people take pleasure in solving problems.

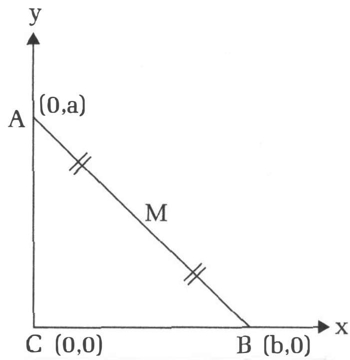
It's notable too that the pleasure is in the *solving* of the problem. Working on a problem with no sense that you're making progress is not pleasurable. In fact, it's frustrating. Then too, there's not great pleasure in simply knowing the answer. I told you the solution to the candle problem; did you get any fun out of it? Think how much more fun it would have been if you had solved it yourself—in fact, the problem would have seemed more clever, just as a joke that you get is funnier than a joke that has to be explained. Even if someone doesn't tell you the answer to a problem, once you've had too many hints you lose the sense that *you've* solved the problem, and getting the answer doesn't bring the same mental snap of satisfaction.

Mental work appeals to us because it offers the opportunity for that pleasant feeling when it succeeds. But not all types of thinking are equally attractive. People choose to work crossword puzzles but not algebra problems. A biography of Bono is more likely to sell well than a biography of Keats. What characterizes the mental activity that people enjoy (Figure 4)?

The answer that most people would give may seem obvious: "I think crossword puzzles are fun and Bono is cool, but math is boring and so is Keats." In other words, it's the content that matters. We're curious about some stuff but not about other stuff. Certainly that's the way people describe our own interests—"I'm a stamp collector" or "I'm into medieval symphonic music." But I don't think content drives interest. We've all attended a lecture or watched a TV show (perhaps against our will) about a subject we thought we weren't interested in, only to find ourselves fascinated; and it's easy to get bored even when you usually like the topic. I'll never forget my eagerness for the day my middle school teacher was to talk about sex. As a teenage boy in a staid 1970s suburban culture, I fizzed with anticipation of any talk about sex, anytime, anywhere. But when the big day came, my friends and I were absolutely disabled with boredom. It's not that the teacher talked about flowers and pollination—he really did talk about human sexuality—but somehow it was still dull. I actually wish I could remember how he did it; boring a bunch of hormonal teenagers with a sex talk is quite a feat.

	6		1		4		5	
		8	3		5	6		
2								1
8			4		7			6
		6				3		
7			9		1			4
5								2
		7	2		6	9		
	4		5		8			7

Fill the 9 × 9 grid so each column, row, and each 3 × 3 box contains the digits 1–9



Prove that the midpoint of the hypotenuse of a right trigangle is equidistant from the vertices of the triangle.

FIGURE 4: Why are many people fascinated by problems like the one shown on the left, but very few people willingly work on problems like the one on the right?

I once made this point to a group of teachers when talking about motivation and cognition. About five minutes into the talk I presented a slide depicting the model of motivation shown in Figure 5. I didn't prepare the audience for the slide in any way; I just put it up and started describing it. After about fifteen seconds I stopped and said to the audience, "Anyone who is still listening to me, please raise your hand." One person did. The other fifty-nine were also attending voluntarily; it was a topic in which they were presumably interested, and the talk had only just started—but in fifteen seconds their minds were somewhere else. The content of a problem—whether it's about sex or human motivation—may be sufficient to prompt your interest, but it won't maintain it.

So, if content is not enough to keep your attention, when does curiosity have staying power? The answer may lie in the difficulty of the problem. If we get a little burst of pleasure from solving a problem, then there's no point in working on a problem that is too easy—there'll be no pleasure when it's solved because it didn't feel like much of a problem in the first place. Then too, when you size up a problem as very difficult, you are judging that you're unlikely to solve it, and are therefore unlikely to get the satisfaction that comes with the solution. A crossword puzzle that is too easy is just mindless work: you fill in the squares, scarcely thinking about it, and there's no gratification, even though you're getting all the answers. But you're unlikely to work long at a crossword puzzle that's too difficult. You know you'll solve very little of it, so it will just be frustrating. The slide in Figure 5 is too detailed to be absorbed with minimal introduction; my audience quickly concluded that it was overwhelming and mentally checked out of my talk.

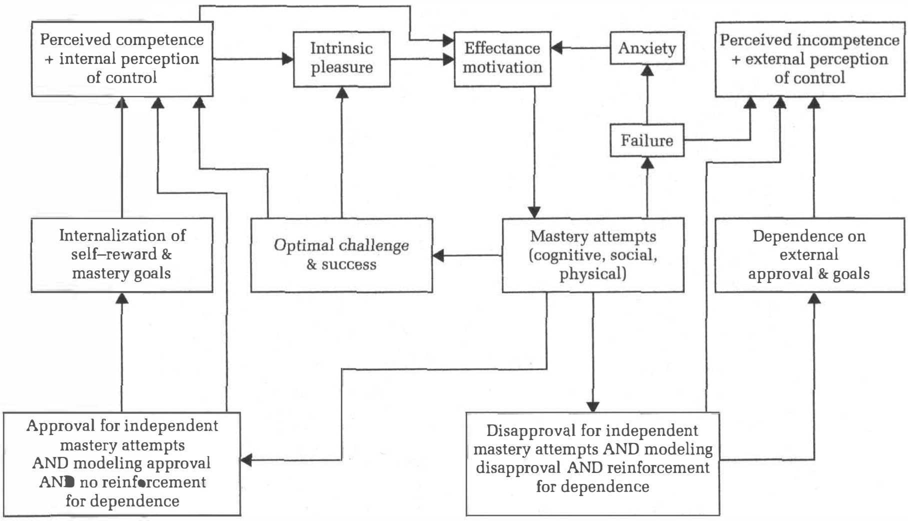


FIGURE 5: A difficult-to-understand figure that will bore most people unless it is adequately introduced.

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.

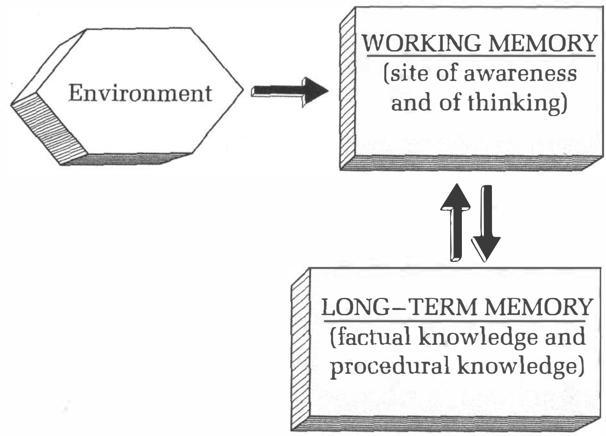


FIGURE 6: Just about the simplest model of the mind possible.

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.

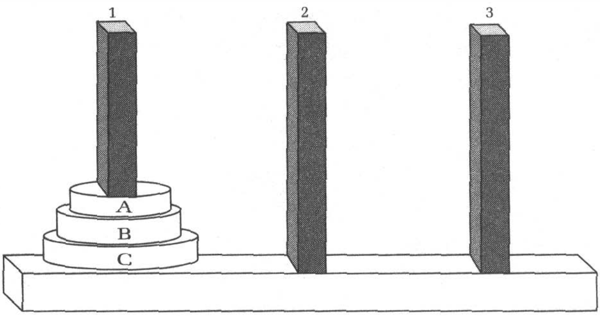


FIGURE 7: The figure depicts a playing board with three pegs. There are three rings of decreasing size on the leftmost peg. The goal is to move all three rings from the leftmost peg to the rightmost peg. There are just two rules about how you can move rings: you can move only one ring at a time, and 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.

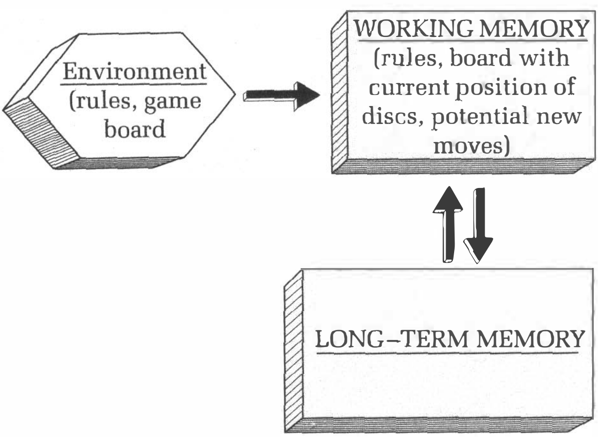


FIGURE 8: A depiction of your mind when you're working on the puzzle shown in Figure 7.

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

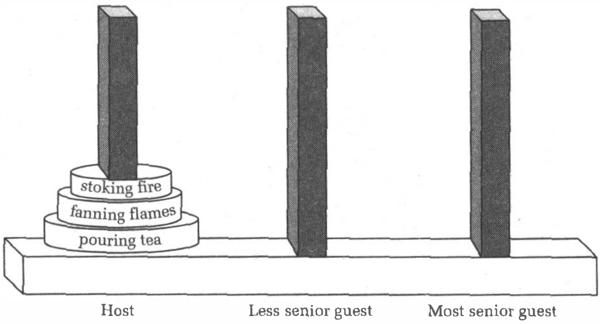


FIGURE 9: The tea-ceremony problem, depicted to show the analogy to the discs-and-pegs problem.

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 there are lots of reasons that a student might or might not enjoy school. (My wife loved it, but primarily for social reasons.) From a cognitive perspective, an important factor is whether or not a student consistently experiences the pleasurable rush of solving a problem. What can teachers do to ensure that each student gets that pleasure?

Be Sure That There Are Problems to Be Solved

By *problem* I don't necessarily mean a question addressed to the class by the teacher, or a mathematical puzzle. I mean cognitive work that poses moderate challenge, including such activities as understanding a poem or thinking of novel uses for recyclable materials. This sort of cognitive work is of course the main stuff of teaching—we want our students to think. But without some attention, a lesson plan can become a long string of teacher explanations, with little opportunity for students to solve problems. So scan each lesson plan with an eye toward the cognitive work that students will be doing. How often does such work occur? Is it intermixed with cognitive breaks? When you have identified the challenges, consider whether they are open to negative outcomes such as students failing to understand what they are to do, or students being unlikely to solve the problem, or students simply trying to guess what you would like them to say or do.

Respect Students' Cognitive Limits

When trying to develop effective mental challenges for your students, bear in mind the cognitive limitations discussed in this chapter. For example, suppose you began a history lesson with a question: "You've all heard of the Boston Tea Party; why do you suppose the colonists dressed as Indians and dumped tea into the Boston harbor?" Do your students have the necessary background knowledge in memory to consider this question? What do they know about the relationship of the colonies and the British crown in 1773? Do they know about the social and economic significance of tea? Could they generate reasonable alternative courses of action? If they lack the appropriate background knowledge, the question you pose will quickly be judged as "boring." If students lack the background knowledge to engage with a problem, save it for another time when they have that knowledge.

Equally important is the limit on working memory. Remember that people can keep only so much information in mind at once, as you experienced when you read the tea-ceremony version of the discs-and-pegs problem. Overloads of working memory are caused by such things as multistep instructions, lists of unconnected facts, chains of logic more than two or three steps long, and the application of a just-learned concept to new material (unless the concept is quite simple). The solution to working memory overloads is straightforward: slow the pace, and use memory aids such as writing on the blackboard that save students from keeping too much information in working memory.

Clarifying the Problems to Be Solved

How can you make the problem interesting? A common strategy is to try to make the material "relevant" to students. This strategy sometimes works well, but it's hard to use for some material. Another difficulty is that a teacher's class may include two football fans, a doll collector, a NASCAR enthusiast, a horseback riding competitor—you get the idea. Mentioning a popular singer in the course of a history lesson may give the class a giggle, but it won't do much more than that. I have emphasized that our curiosity is provoked when we perceive a problem that we believe we can solve. What is the question that will engage students and make them want to know the answer?

One way to view schoolwork is as a series of *answers.* We want students to know Boyle's law, or three causes of the U.S. Civil War, or why Poe's raven kept saying, "Nevermore." Sometimes I think that we, as teachers, are so eager to get to the answers that we do not devote sufficient time to developing the question. But as the information in this chapter indicates, it's the question that piques people's interest. Being *told* an answer doesn't do anything for you. You may have noted that I could have organized this book around principles of cognitive psychology. Instead I organized it around questions that I thought teachers would find interesting.

When you plan a lesson, you start with the information you want students to know by its end. As a next step, consider what the key question for that lesson might be and how you can frame that question so it will have the right level of difficulty to engage your students and so you will respect your students' cognitive limitations.

Reconsider When to Puzzle Students

Teachers often seek to draw students into a lesson by presenting a problem that we believe will interest the students (for example, asking, "Why is there a law that you have to go to school?" could introduce the process by which laws are passed), or by conducting a demonstration or presenting a fact that we think students will find surprising. In either case, the goal is to puzzle students, to make them curious. This is a useful technique, but it's worth considering whether these strategies might be used not only at the beginning of a lesson but also *after* the basic concepts have been learned. For example, a classic science demonstration is to put a burning piece of paper in a milk bottle and then put a boiled egg over the bottle's opening. After the paper burns, the egg is sucked into the bottle. Students will no doubt be astonished, but if they don't know the principle behind it, the demonstration is like a magic trick—it's a momentary thrill, but their curiosity to understand may not be long-lasting. Another strategy would be to conduct the demonstration after students know that warm air expands and cooling air contracts, potentially forming a vacuum. Every fact or demonstration that would puzzle students before they have the right background knowledge has the potential to be an experience that will puzzle students *momentarily,* and then lead to the pleasure of problem solving. It is worth thinking about when to use a marvelous device like the egg-in-the-bottle trick.

Accept and Act on Variation in Student Preparation

As I describe in Chapter Eight, I don't accept that some students are "just not very bright" and ought to be tracked into less demanding classes. But it's naïve to pretend that all students come to your class equally prepared to excel; they have had different preparations, as well as different levels of support at home, and they will therefore differ in their abilities. If that's true, and if what I've said in this chapter is true, it is self-defeating to give all of your students the same work. The less capable students will find it too difficult and will struggle against their brain's bias to mentally walk away from schoolwork. To the extent that you can, it's smart, I think, to assign work to individuals or groups of students that is appropriate to their current level of competence. Naturally you will want to do this in a sensitive way, minimizing the extent to which some students will perceive themselves as behind others. But the fact is that they *are* behind the others, and giving them work that is beyond them is unlikely to help them catch up, and is likely to make them fall still further behind.

Change the Pace

We all inevitably lose the attention of our students, and as this chapter has described, it's likely to happen if they feel somewhat confused. They will mentally check out. The good news is that it's relatively easy to get them back. Change grabs attention, as you no doubt know. When there's a bang outside your classroom, every head turns to the windows. When you change topics, start a new activity, or in some other way show that you are shifting gears, virtually every student's attention will come back to you, and you will have a new chance to engage them. So plan shifts and monitor your class's attention to see whether you need to make them more often or less frequently.

Keep a Diary

The core idea presented in this chapter is that solving a problem gives people pleasure, but the problem must be easy enough to be solved yet difficult enough to take some mental effort. Finding this sweet spot of difficulty is not easy. Your experience in the classroom is your best guide—whatever works, do again; whatever doesn't, discard. But don't expect that you will really remember how well a lesson plan worked a year later. Whether a lesson goes brilliantly well or down in flames, it feels at the time that we'll never forget what happened; but the ravages of memory can surprise us, so write it down. Even if it's just a quick scratch on a sticky note, try to make a habit of recording your success in gauging the level of difficulty in the problems you pose for your students.

One of the factors that contributes to successful thought is the amount and quality of information in long-term memory. In Chapter Two I elaborate on the importance of background knowledge—on why it is so vital to effective thinking.

Notes

*A more eloquent version comes from eighteenth-century British painter Sir Joshua Reynolds: "There is no expedient to which a man will not resort to avoid the real labor of thinking."

†If you couldn't solve it, here's a solution. As you can see, the rings are marked A, B, and C, and the pegs are marked 1, 2, and 3. The solution is A3, B2, A2, C3, A1, B3, A3.