TEACHING CRITICAL THINKING

SOME LESSONS FROM COGNITIVE SCIENCE

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Abstract. This article draws six key lessons from cognitive science for teachers of critical thinking. The lessons are: acquiring expertise in critical thinking is hard; practice in critical-thinking skills themselves enhances skills; the transfer of skills must be practiced; some theoretical knowledge is required; diagramming arguments ("argument mapping") promotes skill; and students are prone to belief preservation. The article provides some guidelines for teaching practice in light of these lessons.

Surprise quiz: Why, except during a full moon, is part of the moon in a shadow?

The most common answer, even among smart undergraduates at the best institutions, is something like this: Earth blocks light from the sun, causing a shadow, and the moon happens to sit on the boundary of that shadow; hence, part of the moon is lit up, while the rest is in darkness.

This answer is, of course, wrong. It reflects a widely held misconception about basic astronomy. More interesting, it illustrates a typical failure to think critically. Students are unaware that they have in mind an explanatory hypothesis and that before accepting it as true, they ought to compare it with others. Another hypothesis is that we are seeing the moon from its side (assuming the moon's "front" is facing the sun), and the darkness is the shadow the moon necessarily creates on itself—the "dark side of the moon." To see how this works, take an orange or a tennis ball and hold it up near a bright light. The shadow and the reason for it are obvious. This alternative hypothesis is not hard to think up, and students immediately see that it is more plausible. They then realize that they had accepted the first without really thinking about it—that is, uncritically.

Almost everyone agrees that one of the main goals of education, at whatever level, is to help develop general thinking skills, particularly critical-thinking skills. Almost everyone also agrees that students do not acquire these skills as much as they could and should. The difficult part is knowing what to do about it. Apparently, we need to generally improve our teaching and our educational systems. But in what ways? What enhancements would best promote the development of critical-thinking skills?

One sensible strategy is to look to science for some guidance. The relevant science in this case is cognitive science, the interdisciplinary science of thinking: what it is, how it works, and how it develops. As John Bruer has argued, cognitive science is the best source we have for genuine knowledge about "what works and why" in teaching (Bruer 1993); critical thinking is just a special case.

I do not think that cognitive science offers the full story by any means. For one thing, it is incomplete and in a continual state of flux. It gives us provisional insights, not the final word. Also, cognitive science provides general or theoretical information, not any kind of detailed recipe for actual teaching. Its findings must be carefully blended with the practical wisdom that teachers have accumulated, both as a profession and as experienced individuals. Third, surprisingly, cognitive scientists do not study critical thinking much, at least not as a topic in its own right. This is partly because the topic is too broad and open-ended to be captured by the cognitive scientist's tightly focused techniques. Partly, it also is because critical thinking in general is a

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neglected topic, despite its importance and broad relevance.

Nevertheless, cognitive scientists do have some contributions to make. They have developed some very general insights into how we think and how we learn, and these can be carried over to critical thinking. They also have studied many phenomena that are particular aspects or dimensions of critical thinking. I have summarized in six succinct "lessons" some of the most important of these insights. The lessons are partly about critical thinking itself, partly about how critical-thinking skills are acquired, and partly about how critical thinking is taught best. They are intended for teachers who wish to help their students strengthen their critical thinking, who understand roughly what critical thinking is but have not investigated the matter closely, and who are not especially familiar with cognitive science. The list is not definitive; there are other important results from cognitive science, and others might make different selections.

Lesson 1: Critical Thinking Is Hard

The first, and perhaps most important, lesson is that critical thinking is hard. Although it can seem quite basic, it actually is a complicated process, and most people are just not very good at it.

The best research on this topic is a huge study conducted by Deanna Kuhn and reported in her book *The Skills of Argument* (1991). Kuhn took a diverse selection of 160 people and, in extended, structured interviews, gave them every opportunity to demonstrate their ability to argue in support of their own opinions. She gathered a huge amount of data, which I summarize as follows: A majority of people cannot, even when prompted, reliably exhibit basic skills of general reasoning and argumentation. For example, most people, when asked, have an opinion on a topic such as why some kids stay away from school. A typical opinion would be something such as, "Some kids stay away from school because their parents do not provide discipline." When asked to justify their opinion, however—to provide some evidence to back it up—more than half of the population flounder. They have plenty of responses to the request for evidence, but what they say is not evidence (let alone good evidence). Such people are not incapable of reason. They can easily follow, or produce, elementary inferences such as, "You don't have a ticket, therefore you can't go in to the theater." The problem is that they do not have a general grasp of the notion of evidence and what would properly count as providing evidence in support of their view on a nontrivial issue such as truancy.

Humans are not naturally critical. Indeed, like ballet, critical thinking is a highly contrived activity. Running is natural; nightclub dancing is less so; but ballet is something people can only do well with many years of painful, expensive, dedicated training. Evolution did not intend us to walk on the ends of our toes, and whatever Aristotle might have said, we were not designed to be all that critical either. Evolution does not waste effort making things better than they need to be, and homo sapiens evolved to be just logical enough to survive, while competitors such as Neanderthals and mastodons died out.

So, if humans are not naturally critical, what kind of thinkers are they? Michael Shermer (2002) describes us as pattern-seeking, story-telling animals. We like things to make sense, and the kinds of sense we grasp most easily are simple, familiar patterns or narratives. The problem arises when we do not spontaneously (and do not know how to) go on to ask whether an apparent pattern is really there or whether a story is actually true. We tend to be comfortable with the first account that seems right, and we rarely pursue the matter further. Educational theorist David Perkins and colleagues have described this as a "makes-sense epistemology"; in empirical studies, he found that students tend to

> act as though the test of truth is that a proposition makes intuitive sense, sounds right, rings true. They see no need to criticize or revise accounts that do make sense—the intuitive feel of fit suffices. (Perkins, Allen, and Hafner 1983,186)

Even if humans were naturally inclined to think critically, it would still be difficult to master because it is what cognitive scientists call a "higher-order skill." That is, critical thinking is a complex activity built up out of other skills that are simpler and easier to acquire. For example, to respond critically to a letter to the newspaper, you must already be able to read and understand the letter (text comprehension), which are built on skills such as being able to recognize words, which in turn is built on finer-grained skills, such as recognizing individual letters. If these lower-level skills are not properly bedded down, critical thinking is not just going to happen; you may as well ask your dog to answer your e-mails.

Furthermore, even if the lower-level skills have been mastered, they have to be combined in the right way. With critical thinking, as with so many other things, the whole is definitely more than the mere aggregate of its parts. Think about tennis, which is a higher-order skill. To be able to play tennis, you must be able to do things like run, hit a forehand, hit a backhand, and watch your opponent. But mastering each of these things separately is not enough. You must be able to combine them into the coherent, fluid assemblies that make up a whole point. Likewise, critical thinking involves skillfully exercising various lower-level cognitive capacities in integrated wholes.

Because critical thinking is so difficult, it takes a long time to become good at it. As a rule of thumb, my guess is that mastering critical thinking is about as difficult as becoming fluent in a second language. Remember all that effort that one puts into learning—or trying to learn—French, German, or Mandarin back at school? Well, that is roughly how difficult it is to become a good critical thinker.

The upshot for teaching critical thinking is that we should not look for magic bullets. Our students will not become Carl Sagans overnight, and no fancy new technology or teaching technique is going to produce dramatic transformations without the necessary time and effort being applied. Critical thinking is more of a lifelong journey than something picked up in a two-week module. However, just because mastery takes such a long time, it is never too early—or too late—to start working on it.

Lesson 2: Practice Makes Perfect

Critical thinking may be difficult, but it certainly is not impossible. Some people do get quite good at it. What does this take?

The key is hidden behind the little word "skill." Everyone knows that mastering a skill takes practice, and lots of it. "Practice makes perfect" is a nugget of folk wisdom that has been extensively investigated by science, and it has come out vindicated: You will not get better without practice, and getting really good takes lots of practice. The skills of critical thinking are no exception.

This has one immediate implication for teaching critical thinking. For students to improve, they must engage in critical thinking itself. It is not enough to learn about critical thinking. Many college professors seem unaware of this point; they teach a course on the theory of critical thinking and assume that their students will end up better critical thinkers. Other teachers make a similar mistake: They expose their students to examples of good critical thinking (for example, having them read articles by professional philosophers), hoping that students will learn by imitation. These strategies are about as effective as working on your tennis by watching Wimbledon. Unless the students are actively doing the thinking themselves, they will never improve.

The scientists who study skills have not simply rediscovered folk wisdom. They have learned quite a bit about the nature and quantity of the practice needed for mastery. The foremost expert in this area is Karl Anders Ericsson, who with his colleagues has studied at great length how the very top people in many different fields become as good as they are (Ericsson and Charness 1994). He has found that excellence results primarily from a special sort of practice, which he calls "deliberate." The characteristics of deliberate practice are well defined:

1. It is done with full concentration and is aimed at generating improvement.
2. It is not only engaging in the skill itself but also doing special exercises designed to improve performance in the skill.
3. It is graduated, in the sense that practiced activities gradually become harder, and easier activities are mastered through repetition before harder ones are practiced.
4. There is close guidance and timely, accurate feedback on performance.

Ericsson found that achieving the highest levels of excellence in many different fields was strongly related to the quantity of deliberate practice. Interestingly, Ericsson even found a remarkable uniformity across fields in the amount of practice required to reach the very highest levels; it generally takes about ten years of practicing for approximately four hours a day.

Although Ericsson did not study critical thinking specifically, it is reasonable to assume that his conclusions will hold true for critical thinking. This means that our students will improve their critical-thinking skills most effectively just to the extent that they engage in lots of deliberate practice in critical thinking. Crucially, this is not just thinking critically about some topic (for example, being "critical" in writing a philosophy essay). It also involves doing special exercises whose main point is to improve critical-thinking skills themselves.

Thus, critical thinking cannot be treated as just a kind of gloss on educational content made up of other "real" subjects. Students will not become excellent critical thinkers merely by studying history, marketing, or nursing, even if their instruction is given a "critical" emphasis (as it should be). Critical thinking must be studied and practiced in its own right; it must be an explicit part of the curriculum.

Lesson 3: Practice for Transfer

One of the biggest challenges in learning new skills, particularly general skills such as critical thinking, is the problem of transfer. In a nutshell, the problem is that an insight or skill picked up in one situation is not, or cannot be, applied in another situation. For example, if someone has just learned how to calculate the per-kilogram price for packaged nuts, they should then be able to calculate the per-kilogram price for packaged chips; if they cannot, we would say that the learning has failed to transfer from nuts to chips.

A transfer of acquired knowledge and skills certainly does occur to some extent; otherwise, education would be an exceedingly laborious business. The problem is that it happens much less than one might naively expect (Detterman 1993). This affects critical thinking as much as any other skill. Indeed, critical thinking is especially vulnerable to the problem of transfer because critical thinking is intrinsically general in nature. Critical-thinking skills are, by definition, ones that apply in a very wide range of domains, contexts, and so on, and so there is plenty of territory into which they can fail to transfer.

The closest thing we have to a solution to the transfer problem is the recognition that there is a problem that must be confronted head-on. As psychologist Dianne Halpern put it (1998), we must teach for transfer. We cannot simply hope and expect that critical-thinking skills, once learned in a particular situation, will be applied spontaneously in others. Rather, students also must practice the art of transferring the skills from one situation to another. If they can master that higher-order skill of transfer, then they do not have a problem of transfer for the primary skill.

This might sound mysterious, but it often can be quite straightforward. For example, first have students practice a primary critical-thinking skill in some specific context, such as assessing the credibility of authors of letters in the day's newspaper, but do not stop there. Next, get them to abstract for themselves what they have been doing in such a way that they can see that they had been doing something general, which just happened to have been applied to authors of letters. Then, challenge them to identify some other context or domain in which that abstracted skill might be properly applied and go ahead and apply it. For example, a student might recognize that the credibility of a textbook's author being used in another of their subjects can be assessed in a similar way.

Lesson 4: Practical Theory

Many people enjoy beer, but very few know much about beer itself. Even people who consume lots of beer typically do not know that much about it. They are, in this sense, unsophisticated beer drinkers.

Of course, there is nothing intrinsically wrong with that. There is no obligation to know the difference between hops, barley, and wort. However, if you do choose to investigate beer, you usually will find that you can appreciate your beer more. Furthermore, knowing about beer will allow you to do things you cannot otherwise do—for example, match beer with

food, produce your own beer, or even run your own microbrewery.

Getting into beer is, in part, learning what in an academic vein we might call the theory of beer. You have to learn a new vocabulary, that is, new words and the corresponding concepts, and understanding the concepts means mastering a body of knowledge, including the relevant parts of chemistry and biology. Much the same is true of critical thinking: Beyond a certain point, improvement demands acquiring some theory. The serious critical thinker understands the theory of critical thinking. This means, in part, acquiring the specialist vocabulary. Instead of saying, "That argument sucks," the critical thinker can say that she does not accept the conclusion, even though she grants the premises, because the inference is an example of the fallacy of post hoc ergo propter hoc. What is so good about having the theory? Why does it help improve critical thinking?

Knowledge of the theory allows you to perceive more of what is going on. In the case of beer, understanding the vocabulary of beer flavors helps you distinguish flavors that, although always present, are invisible to the naive drinker. In critical thinking, having command of the "lingo" is like having x-ray vision into thinking. For example, if you know what "affirming the consequent" is, you can more easily spot examples of poor reasoning, because reasoning fitting that particular pattern will be more likely to jump out at you.

This improved insight is the basis for self-monitoring and correction. As described above, improvement requires lots of deliberate practice. The better you can "see" what is going on, the more effectively you can understand what you are doing and how you can do it better.

Similarly, a grasp of the theory provides the foundation for explicit guidance and feedback from a teacher or coach. Instructions must be expressed verbally, and the more nuanced the vocabulary, the more that can be communicated. The student who does not understand what we are saying about critical thinking cannot follow our instructions or respond to our feedback; the student cannot be guided, beyond a certain point.

I suggested earlier that college instructors often make the mistake of thinking that they can teach critical-thinking skills by teaching the theory of critical thinking, but the real mistake is not teaching theory as such. The mistake, rather, is to only teach theory or to overemphasize theory relative to practice. The mistake is to think that skills naturally follow from knowing the theory. They do not (Dreyfus and Dreyfus 1986). However, the all-important practice is more effective when supplemented by appropriate levels of theoretical understanding.

If you like, a bit of theory is like the yeast that makes bread rise. You only need a small amount relative to the other ingredients, but that small amount is crucial for a good loaf. Note also that if you have nothing but yeast, you have no loaf at all.

Is this just stating the obvious? No, because in actual practice, we do not provide students with any, or nearly enough, theory. Most students never undergo any dedicated instruction in critical thinking and stumble through their entire school and college educations without ever learning much about what they are trying to do (Graff 2003). The way we generally go about cultivating critical thinking is to expect that students somehow will pick it all up through some mysterious process of intellectual osmosis. The lesson from cognitive science is that if we want students to substantially improve their skills, we must at some point help them develop theoretical understanding as a complement to the crucial hands-on know-how (Anderson, Reder, and Simon 2000). As Deanna Kuhn put it,

> The best approach . . . may be to work from both ends at once—from a bottom-up anchoring in regular practice of what is being preached so that skills are exercised, strengthened, and consolidated as well as from a top-down fostering of understanding and intellectual values that play a major role in whether these skills will be used. (1999, 24)

Lesson 5: Map it Out

A core part of critical thinking is handling arguments. By "argument," I do not mean an angry dispute; rather, I use the term the way logicians do, to refer to a logical structure. As defined in the classic Monty Python sketch "The Argument Clinic,"

> A: An argument is a connected series of statements intended to establish a definite proposition.
>
> B: No it isn't.
>
> A: Yes it is! (Chapman and Python 1989)

Arguments constitute a body of evidence in relation to some proposition (an idea that is true or false). The proposition is expressed in some claim (for example, the claim that Houdini was a fraud) and the evidence is expressed in other claims (nobody could have escaped from a locked trunk under a frozen river). The evidence can form a complex web or hierarchy, with some claims both supporting others and being supported by further claims (that nobody could have escaped from a locked trunk under a frozen river may itself be supported by further claims).

There is a feature of the way we handle arguments that is so automatic and pervasive that it is almost invisible: Arguments are presented or expressed in streams of words, whether written or spoken. Here are some mundane examples:

- writing a letter to the editor of a newspaper, arguing for a certain point
- publishing an article in a journal or defending a position in an academic debate
- making a speech in Parliament supporting some new law
- arguing your position in a family dispute around the kitchen table.

In all of these cases and endless others like them, the argument (the abstract logical structure) is expressed in sequences of words or sentences that stream out either as ink on the page or as sounds in the air. Argumentation, in short, is one word after another.

Nothing could be more natural, it seems, than expressing the argument in a linear verbal sequence. Indeed, most people have not the faintest idea that there is any alternative. However, there is an alternative, one that is obvious enough after a little reflection. If evidence forms complex hierarchical structures, then those structures can be diagrammed. Put another way, we can draw maps that make the logical structure of the argument completely explicit.

For example, consider the following passage:

> How much is your life worth to you? On the face of it, that's an idiotic question.

> No amount of money could compensate you for the loss of your life, for the simple reason that the money would be no good to you if you were dead. (Holt 2004)

The passage expresses in a verbal stream an argument about the origin of some unusual waves. The same argument can be laid out in an argument map (figure 1).

Like any map, this diagram adopts a particular set of conventions. One is that the main point being asserted is put at the top (or, more technically, at the root of the argument "tree"). The arrows indicate that one claim, or group of claims, is evidence in relation to another; the word "reason" and the use of the color green would indicate that they are supporting evidence. Once you are familiar with these elementary conventions, you immediately can "see" the logical structure of the reasoning.

In this example, the reasoning is quite simple in its basic structure, and the diagram may seem to provide little added benefit. The more complex reasoning becomes, however, the more it helps present the structure visually. Analogously, if a stranger asks for directions, verbal instructions may suffice if their destination is just around the corner, but a journey across town needs a proper map.

Now, the crucial result from cognitive science is that students' critical-thinking skills improve faster when instruction is based on argument mapping. The main evidence for this comes from studies in which students are tested before and after a one-semester undergraduate critical-thinking course. Students in classes based heavily on argument mapping consistently improve their skills much faster than students in conventional classes (Twardy, forthcoming; van Gelder, Bissett, and Cumming 2004). Indeed, one semester of instruction based on argument mapping can yield reasoning skill gains of the same magnitude as would normally be expected to occur over an entire undergraduate education.

What is the source of this advantage? From a learning perspective, argument maps have a number of advantages over standard verbal presentations:

1. They make reasoning more easily understandable. Students can focus their attention on critical thinking rather than getting bogged down just trying to understand the reasoning as presented in ordinary text.
2. Once students can see the reasoning, they can more easily identify important issues, such as whether an assumption has been articulated, whether a premise needs further support, or whether an objection has been addressed.
3. When arguments are presented in diagrammatic form, students are better able to follow extended critical-thinking procedures. For example, evaluating a multilayered argument involves many distinct steps that should be done in a certain order.
4. When arguments are laid out in diagrams following strict conventions, a teacher immediately can "see" what the student is thinking. One instructor has described argument mapping as giving "x-ray vision into the students' minds." This clarity of insight allows the teacher to give much more rapid and targeted feedback, and the student understands better where the feedback applies and what needs to be done to correct problems.

In short, argument maps are a more transparent and effective way to represent arguments, and so they make the core operations of critical thinking more straightforward, resulting in faster growth in critical-thinking skills.

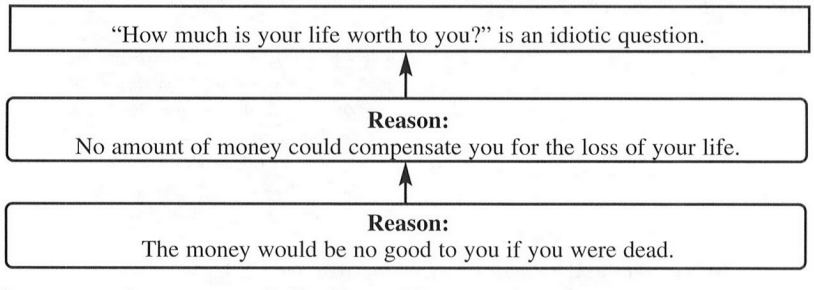

FIGURE 1. Argument map. In similar diagrams using color, the arrows and boxes would be green to signify supporting evidence.

If argument maps are so great, why are they not used much? An important part of the explanation is that it usually is a lot easier to work in the purely verbal medium than in diagrams. As a practical matter, representing arguments in diagrams tends to be slow and cumbersome. This is starting to change, however, with personal computers more widely available and the emergence of software packages specially designed to support argument mapping (Kirschner, Buckingham Shum, and Carr 2002).

From a practical perspective, this means that wherever feasible, arguments should be displayed in the form of argument maps. One strategy is to require students to provide a map of their reasoning whenever they hand in a piece of written work that involves presenting some kind of reasoning or argument.

Lesson 6: Belief Preservation

Francis Bacon, the great seventeenth-century philosopher of science, once said,

> The mind of man is far from the nature of a clear and equal glass, wherein the beams of things should reflect according to their true incidence; nay, it is rather like an enchanted glass, full of superstition and imposture, if it be not delivered and reduced. (Bacon 1974)

In other words, the mind has intrinsic tendencies toward illusion, distortion, and error. To some extent, these are just features of the "hard-wired" neural equipment we inherited through the accidental process of evolution. To some extent, they are the result of common patterns of growth and adaptation—the way our brains develop as we grow up on a planet such as Earth. To some extent, they also are "nurtured," that is, inculcated by our societies and cultures. Yet, whatever their origin, they are universal and ineradicable features of our cognitive machinery, usually operating quite invisibly to corrupt our thinking and contaminate our beliefs.

These tendencies are known generically as "cognitive biases and blindspots." They obviously are important for the critical thinker, who ought to be aware of them and either eliminate them entirely, if possible, or at least compensate for their influence, much as a skillful archer adjusts her aim to allow for a breeze.

There are literally dozens of biases and blindspots, some operating as powerful traps, others as subtle tendencies (see, for example, Piatelli-Palmarini 1994). An introduction to critical metacognition easily could occupy this whole essay, but I will discuss just one bias, one of the most profound and pervasive of the lot: belief preservation.

At root, belief preservation is the tendency to make evidence subservient to belief, rather than the other way around. Put another way, it is the tendency to use evidence to preserve our opinions rather than guide them (Douglas 2000). It is nicely illustrated by this story from Stuart Sutherland:

> When I was quite young, I conducted a routine piece of motivation research on a well-known brand of gin. I interviewed people throughout Britain to obtain their reactions to the bottle and label, and to ascertain the product's "brand image." I gave an oral presentation of my results to a party from the distiller's company, which was headed by the managing director, a large bluff Scotsman. When I said anything with which he agreed, he would turn to his colleagues and announce with much rolling of r's, "Dr. Sutherland's a very smart man. He's absolutely right." When, however, my findings disagreed with his own views, he said "Rubbish. Absolute rubbish." I need never have undertaken the study, for all the notice he took of it. (1992, 134)

When we strongly believe something (or strongly desire it to be true), then we tend to do the following:

1. We seek evidence that supports what we believe and do not seek and avoid or ignore evidence that goes against it. For example, the socialist seeks evidence that capitalism is unjust and ill-fated and ignores or denies evidence of its success; the capitalist tends to do exactly the reverse.
2. We rate evidence as good or bad depending on whether it supports or conflicts with our belief. That is, the belief dictates our evaluation of the evidence, rather than our evaluation of the evidence determining what we should believe. For example, Bjørn Lomborg's book *The Skeptical Environmentalist* (2001) presented lots of evidence running counter to standard "green" positions. Predictably enough, when reviewing the book, environmentalists tended to regard the data and arguments as much worse than did their anti-environmentalist counterparts.
3. We stick with our beliefs even in the face of overwhelming contrary evidence as long as we can find at least some support, no matter how slender. A dramatic example from World War II is Stalin's calamitous insistence that Hitler was not going to invade the Soviet Union, despite the clear evidence of German forces massing on the border. Stalin's mistake was not that he had no basis for thinking Hitler would not invade; rather, it was failing to surrender that belief when that basis was outweighed by contrary indications.

Belief preservation strikes right at the heart of our general processes of rational deliberation. The ideal critical thinker is aware of the phenomenon, actively monitors her thinking to detect its pernicious influence, and deploys compensatory strategies. Thus, the ideal critical thinker

- puts extra effort into searching for and attending to evidence that contradicts what she currently believes;
- when "weighing up" the arguments for and against, gives some "extra credit" for those arguments that go against her position; and
- cultivates a willingness to change her mind when the evidence starts mounting against her.

Activities like these do not come easily. Indeed, following these strategies often feels quite perverse. However, they are there for self-protection; they can help you protect your own beliefs against your tendency to self-deception, a bias that is your automatic inheritance as a human being. As Richard Feynman said, "The first principle is that you must not fool yourself—and you are the easiest person to fool" (Hutchings 1997).

Key words: critical thinking, cognitive science

NOTE

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