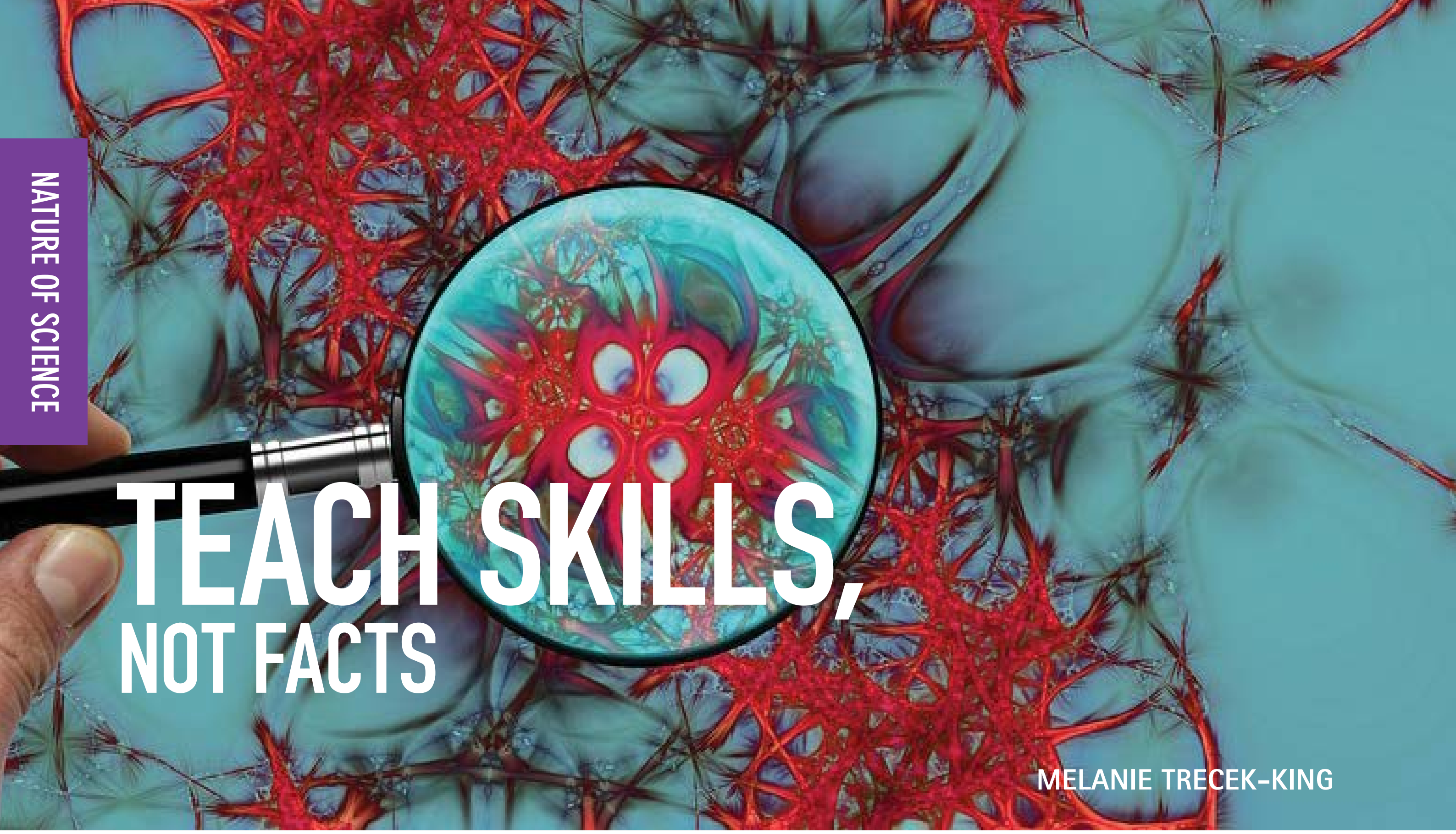

TEACH SKILLS, NOT FACTS

MELANIE TRECEK-KING

Why are all students required to take science? Is it to memorise science facts, or to foster critical thinking and science literacy skills? Why is it important for students to develop these skills? How do we help students learn them?

The moment is burned into my brain like a flashbulb memory—I was teaching 'Introduction to Biology', a course for students not majoring in science, and noticed that my students looked completely deflated. It was at this moment that I realised that my students were not going to remember, let alone use, what they were learning past the exam. Worse, any fears and anxieties they associated with science would continue to haunt them. I had squandered their one opportunity to gain the empowerment that comes with science literacy and critical thinking. This realisation hit me like a ton of bricks.

I had been teaching this course for over a decade, eager to convince my students that science is awesome, that it improves the quality of their lives, and that science literacy is essential in today's world. Biology is the study of life, after all, and science is one of the most reliable ways of knowing. I thought I had a solid case. Unfortunately, few of my students seemed to agree with me. I wouldn't (necessarily) say they hated science, but they were certainly science phobic. A common complaint I heard from them is that they shouldn't be required to take science classes when they intended to major in business, literature, or art. Why should they spend their time (and money) learning about the structure of cell membranes or evolution? And, honestly, I could see their point. As much as I find these topics fascinating and worthy of study, I knew what students were really learning was how to memorize information to regurgitate at exams. So I asked myself—why are nearly all students, regardless of the majors or career paths they are likely to choose, required to take science? The obvious answer seemed to be to foster critical thinking and science literacy. But what does that mean?

Critical thinking and science literacy

Thankfully, I stumbled upon a quote by Carl Sagan: *"If we teach only the findings and products of science—no matter how useful and even inspiring they may be—without communicating its critical method, how can the average person possibly distinguish science from pseudoscience?"* He was right. Science is so much more than a bunch of facts to memorize. It is a process. It is a way of learning about the world, of trying to get closer to the truth by subjecting explanations to testing, and critically scrutinizing the evidence. It is not just **what** we know; it is **how** we know. Basically, science is good thinking.

While nearly all educators say that teaching critical thinking skills and science literacy is important, many students graduate without showing an improvement in either. One very likely reason is that few instructors were formally taught either of these skills or can define them. So, what is critical thinking? There are many definitions, but essentially critical thinking is 'reasonable, reflective thinking that is focused on deciding what to believe and do'. And science literacy is more than just memorising facts. Scientifically literate people understand scientific reasoning and are able to draw reasonable conclusions from the available evidence. They are able to evaluate hypotheses, arguments, conclusions, and their own beliefs. And they're aware of the cognitive biases and logical fallacies that may impact our ability to evaluate evidence and draw fair conclusions. Both these skills are essential to help students navigate their world—today and tomorrow. They can empower students to make better decisions and inoculate minds against the misinformation and disinformation that is currently all too prevalent in our society.

The good news is that, in theory, science courses are the perfect vehicles to teach critical thinking and science literacy. The bad news is that most science courses focus on memorising facts rather than developing skills. But facts are forgettable and widely available. Plus, many of the facts we teach in class will most likely change. After all, science is a never-ending process of weeding out bad ideas and building on good ones.

I will fully admit to being part of the problem. Like many other science educators, I had assumed that, since critical thinking is at the heart of scientific inquiry, I was teaching it in my classes. And, of course, I believed that in teaching facts, I was teaching science literacy! I honestly didn't realize how wrong I was. The global pandemic has made clear the importance of understanding the nature of scientific inquiry and the value of science to society.[1] I wonder how students who took my 'introductory bio' course all those years ago made sense of the pandemic, and if the facts I taught them provided them with the tools to understand coronaviruses, mRNA vaccines, or hydroxychloroquine. The world changed. Knowledge changed. My students needed skills for the future, and I had failed them. If we don't teach students the process of science, how will they be able to differentiate between reliable and unreliable claims? And isn't **that** the point of science education?

Changing focus

I convinced my institution to replace the introductory level biology course that I had been teaching with a new one, called **Science for Life**, that focuses less on the findings of science and almost exclusively on critical thinking and science literacy.[2] One of the main goals of this course is to evaluate evidence for claims to determine how we know something. Another is to learn to recognize the characteristics of good science by evaluating bad science, pseudoscience, and science denial. The entire course is centred around empowering students to make better decisions to help them live better lives.

Unlike most science classes that start with the scientific method, I begin with witches. Centuries ago, being accused of witchcraft and "confessing" under torture were sufficient evidence to convict and sentence a person (usually a woman) to death. Because most students today don't believe that diseases and storms are caused by witches casting spells, they are able to more skeptically examine the supposed evidence and explore why people at the time had such strong beliefs. Through this, they recognise that while we like to think that our beliefs come by rationally following evidence, more often than not, we form beliefs (like of a woman being a witch) in irrational ways and look backward for justifications (see **Fig. 1**).

Our discussion naturally leads to epistemological questions, such as how we know what we know, and how knowing is different from believing. Richard Feynman famously said, *"The first principle is that you must not fool yourself, and you are the easiest person to fool."* Unfortunately, most of us think we're immune! To prove to students how easily they can be fooled, I give them astrology-based 'personality assessments', which nearly all of them

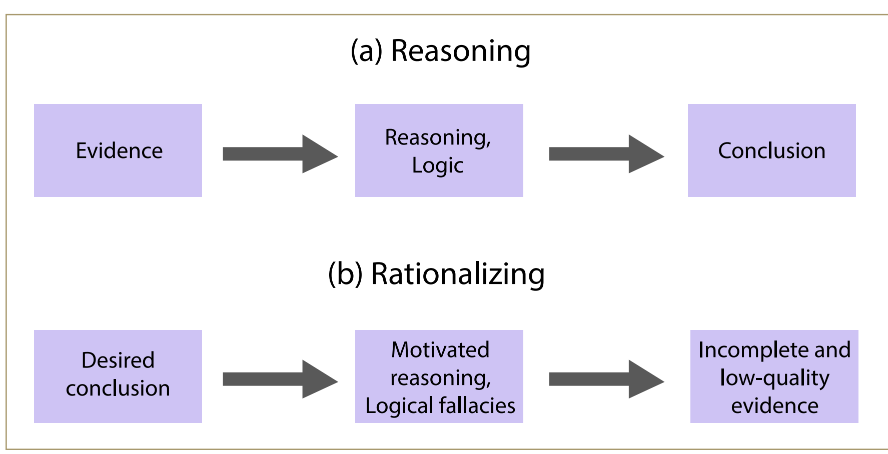

Fig. 1. The difference between reasoning and rationalizing. (a) Reasoning is following evidence to a logical conclusion. (b) Rationalising is selecting evidence to justify a conclusion.

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report as being highly accurate. It is only when they learn that all of them have received the same results do they realize that they've been conned. After I apologize and explain why I lied to them, they're more open to learning skills, such as skepticism, that can protect them from being fooled. While many students confuse skepticism with cynicism or denialism, true skepticism is simply proportioning beliefs to the evidence and is, therefore, an essential characteristic of science.

To equip students with the skills necessary to evaluate claims, I provide them with a toolkit, summarized by the acronym FLOATER.[3] The principles in FLOATER (Falsifiability, Logic, Objectivity, Alternative explanations, Tentative conclusions, Evidence, and Replicability) encapsulate the essence of critical thinking and the process of science. Through repeated practice, students learn to use scientific reasoning to evaluate claims, because pseudoscientific and unreliable claims fail at least one of the rules in FLOATER.

The next lesson is one of the most important ones in the course—the limits of perception and memory. For many, personal experiences are the best way to "know" something. Whether it is believing in UFOs because they've "seen" one or that homeopathy is effective because it "worked" for them, we often fail to recognize that our perceptions are subjective and highly biased, and that our memories are flawed and unreliable. Understanding this is essential for us to know why anecdotes, including one's personal experiences, are unreliable evidence.

We then dive into metacognition, or thinking about thinking. Since our brains have to process a lot of information, and they're lazy, much of this is done on autopilot. This fast, intuitive thinking uses mental short-cuts (or heuristics) that can lead to errors (or cognitive biases). These errors cause our thinking to deviate from reality. Ultimately, the goal is to teach students how to think better by being aware of how they are thinking, and recognizing the limits of what they know.

After students have a better appreciation of how flawed their thinking can be, and the importance of skepticism, we turn to information literacy. Information affects how we think and the decisions we make, yet it can be difficult to distinguish reliable from unreliable information. In fact, we are most likely to fall for misinformation when it confirms what we already believe and/or triggers strong emotions. Thankfully, the concepts covered in the course thus far provide students with the background knowledge to skeptically evaluate sources and claims online. This also helps students to understand the importance of peer review in the process of science. While many science courses teach students how to read primary literature, I don't think that is helpful or necessary. It may even be unrealistic to expect anyone, especially someone who has only taken a few basic courses in science, to rely on jargon-rich articles published in professional journals for making decisions in their daily lives. Instead, it is important that students recognize the limits of their knowledge, and, more broadly, learn how to be good consumers of information.

By the time I introduce the process of science, students have an understanding of why science is reliable and necessary. To reiterate—science is good thinking. We are all biased and irrational; and at its core, science is a way of knowing—a way that recognizes and corrects for our biases. Consider the double-blind, randomized, controlled trials used to test new medications. Every aspect of these studies—such as the blinding, use of placebos, and random sampling—is designed to correct for the cognitive biases that can interfere with determining whether the drug actually works. By building up a justification for science, the logic of the scientific process falls into place.

Speaking of the scientific method, there isn't one, and we do our students a disservice when we teach it as such. While most textbooks start with a recipe-like formula, from observation to hypothesis to experiment, most science does not follow these steps. Science is a community of experts using diverse methods to gather evidence and scrutinize claims. There are endless ways to do science. For example, not all science uses controlled experiments. Observational science, such as discovery science, historical science, and epidemiology, collects data in the 'real world'. Importantly, different types of studies provide different types and qualities of evidence. A broader understanding of the nature of science, which is essentially evidence-based thinking, equips students to evaluate the evidence for any particular claim.

Throughout the course, I use lectures, quizzes, case studies, and assignments to explore real-world issues relevant to students, and provide opportunities to practice evaluating claims. Topics include ghosts, psychics, fake news, fad diets, crystal healing, conspiracy theories, Bigfoot, the MMR vaccine and the autism "controversy", homeopathy, astrology, and climate change denial. Since many students believe in various forms of pseudoscience, its inclusion in the course increases engagement and teaches them how to recognize pseudoscience in their daily lives. Importantly, these issues help students understand that it is important to think critically because being fooled can lead to real harm (see **Box 1**).

Finally, many activities are based on the inoculation theory (which is similar to how vaccines work) for misinformation. Basically, exposure to a bit of misinformation can help build up immunity to the real thing. In some activities, students use humour to create misinformation, such as an advertisement for a pseudoscientific, alternative medicine product and a discussion in which they use fallacies to argue why they should not fail the course.

Box 1. Some student testimonials:

Testimonial 1: *"Our memories and how they can be changed by simple suggestions that you didn't even pick up on. A memory was always a fact to me, like playing back a recording. Now I understand how wrong I was. This was even more important to know and use in my profession as a police officer."*

Testimonial 2: *"Over the duration of this course, I've come to realize that a lot of the issues with our society are simply because we are bombarded with information that exists at our fingertips, and that is pushed at us from numerous sources, all too willing to confirm our beliefs rather than impart facts. If people knew how to be properly skeptical, and how to do real research into the credibility of sources and how to find factual information, this would be a much different world."*

Testimonial 3: *"For most of my life, I assumed skepticism was having a negative outlook on life. Now I know it is actually a vital tool we should all use while taking in information in our daily lives. I think the most valuable thing I've learned is that evidence is vastly underrated and overlooked in most people's everyday lives."*

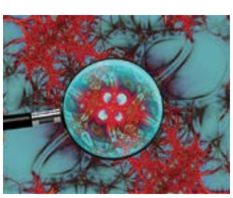
Testimonial 4: *"Everything in this course was outstanding! I already hold a BS in Space Studies from another university and thought I had a good handle on the scientific process. This class really showed how little I knew about the scientific process and how to critically think while being skeptical of the evidence provided. Would highly recommend this course be mandatory for all majors in the country."*

Parting thoughts

The ability to think critically and be scientifically literate has never been more important. We owe it to our students (and society) to teach them curiosity, skepticism, and humility. This is especially true for those students who are likely to take science courses only for a few years. These courses are often the last chance we have to teach students the critical thinking and science literacy skills necessary to be informed citizens.

It is possible to teach these skills, but they cannot just be a component of the curriculum; they have to **be** the curriculum. Instead of teaching students **what** to think, good science education teaches them **how** to think. By emphasizing process over content, students gain the skills necessary to think better and therefore make better decisions. The premise of this kind of education is intellectual empowerment. I tell students at the end of every class, *"Thinking is power. So demand evidence and think critically!"*

Key takeaways



- Science is good thinking. Good science education focusses on how to think rather than on what to think.
- Helping students develop critical thinking and science literacy skills enables them to evaluate hypotheses, arguments, conclusions, and their own beliefs.
- Both these skills are essential for students to navigate their worlds, and can empower them to make better decisions.
- A course dedicated to teaching these skills may help students distinguish scientific facts from misinformation and pseudoscience, even as knowledge and facts change, and new facts emerge.
- Teaching skills and not facts could make science more meaningful and useful even to those students who may not pursue science as a profession in the future.

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Notes:

1. This article was first published in Thinking is Power and is available here: https://thinkingispower.com/from-non-majors-biology-to-critical-thinking-an-educators-journey/. An updated version was published in Skeptical Inquirer and is available here: https://skepticalinquirer.org/2021/12/teach-skills-not-facts/.
2. Source of the image used in the background of the article title: Network. Credits: geralt, Pixabay. URL: https://pixabay.com/photos/annoy-network-magnifying-glass-3991596/. License: CC-BY-SA.

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