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Your Scientific Reasoning Is More Flawed Than You Think

New concepts don't replace incorrect ones: they just learn to live together

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It takes longer to accurately recall counterintuitive theories. *Image: iStock / Frank Ramspott*

In one sense, science educators have it easy. The things they describe are so intrinsically odd and interesting — invisible fields, molecular machines, principles explaining the unity of life and origins of the cosmos — that much of the pedagogical attention-getting is built right in. Where they have it tough, though, is in having to combat an especially resilient form of higher ed's nemesis: the aptly named (if irredeemably clichéd) 'preconceived idea.' Worse than simple ignorance, naïve ideas about science lead people to make bad decisions with confidence. And in a world where many high-stakes issues fundamentally boil down to science, this is clearly a problem.

Naturally, the solution to the problem lies in good schooling — emptying minds of their youthful hunches and intuitions about how the world works, and repopulating them with sound scientific principles that have been repeatedly tested and verified. Wipe out the old operating system, and install the new. According to a recent paper by Andrew Shtulman and Joshua Valcarcel, however, we may not be able to replace old ideas with new ones so cleanly. Although science as a field discards theories that are wrong or lacking, Shtulman and Valcarcel's work suggests that individuals —even scientifically literate ones — tend to hang on to their early, unschooled, and often wrong theories about the natural world. Even long after we learn that these intuitions have no scientific support, they can still subtly persist and influence our thought process. Like old habits, old concepts seem to die hard.

Testing for the persistence of old concepts can't be done directly. Instead, one has to set up a situation in which old concepts, if present, measurably interfere with mental performance. To do this, Shtulman and Valcarcel designed a task that tested how quickly and accurately subjects verified short scientific statements (for example: "air is composed of matter."). In a clever twist, the authors interleaved two kinds of statements — "consistent" ones that had the same truth-value under a naive theory and a proper scientific theory, and "inconsistent" ones. For example, the statement "air is composed of matter" is inconsistent: it's false under a naive theory (air just seems like empty space, right?), but is scientifically true. By contrast, the statement "people turn food into energy" is consistent: anyone who's ever eaten a meal knows it's true, and science affirms this by filling in the details about digestion, respiration and metabolism.

Shtulman and Valcarcel tested 150 college students on a battery of 200 such statements that included an equal and random mix of consistent and inconsistent statements from several domains, including astronomy, evolution, physiology, genetics, waves, and others. The scientists measured participants' response speed and accuracy, and looked for systematic differences in how consistent vs. inconsistent statements were evaluated.

If scientific concepts, once learned, are fully internalized and don't conflict with our earlier naive concepts, one would expect consistent and inconsistent statements to be processed similarly. On the other hand, if naive concepts are never fully supplanted, and are quietly threaded into our thought process, it should take take longer to evaluate inconsistent statements. In other words, it should take a bit of extra mental work (and time) to go against the grain of a naive theory we once held.

This is exactly what Shtulman and Valcarcel found. While there was some variability between the different domains tested, inconsistent statements took almost a half second longer to verify, on average. Granted, there's a significant wrinkle in interpreting this result. Specifically, it may simply be the case that scientific concepts that conflict with naive intuition are simply learned more tenuously than concepts that are consistent with our intuition. Under this view, differences in response times aren't necessarily evidence of ongoing inner conflict between old and new concepts in our brains — it's just a matter of some concepts being more accessible than others, depending on how well they were learned.

There are, though, a few lines of evidence arguing against this interpretation. First, the authors found that participants who had best mastered scientific concepts (determined by their overall accuracy) were especially slow to verify inconsistent statements. A learning-based explanation of performance would have predicted the opposite — that mastery and speed should go hand in hand. More convincingly, a different study has shown that even those who've achieved an extremely high level of competence in a specific scientific field are still prone to make classifications based on naive, early concepts from childhood. In a speeded classification task analogous to Shtulman and Valcarcel's, university biology professors were found to take longer to classify plants as living relative to moving nonliving things, a bias toward equating motion with life that is evident in young children.

Taken together, these findings suggest that we may be innately predisposed to have certain theories about the natural world that are resilient to being drastically replaced or restructured. These naive theories provide hunches and rules of thumb that likely helped us survive long before we needed to contemplate the atom, cells, or relativity. While some theories of learning consider the unschooled mind to be a 'bundle of misconceptions' in need of replacement, perhaps replacement is an unattainable goal. Or, if it is attainable, we may need to rethink how science is taught.

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