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Science, misinformation, and the role of education

"Competent outsiders" must be able to evaluate the credibility of science-based arguments

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With the internet and social media providing a vehicle for conspiracy theorists and snake-oil salesmen, education must provide tools to help make informed choices. PHOTO: FILIPPOBACCI/ISTOCK.COM

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Because of the limits to our knowledge and time, we all depend on the expertise of others. For example, most readers of *Science* accept the anthropogenic origin of climate change. Yet far fewer have actually read a report of the Intergovernmental Panel on Climate Change (IPCC), let alone evaluated the evidence and arguments. Nevertheless, we trust its claims because we rely on the credibility of its authors, the social practices of peer review used to vet any theoretical biases and errors, and the fact that it represents a consensus report of the relevant experts. Alternatively, we can choose to trust the media that report its findings. Amid increasing concern about trust in science being undermined by an ocean of misinformation ([1-3]), we consider how scientists, science curricula, and science educators must help equip individuals to evaluate the credibility of scientific information, even if the science is beyond their understanding ([4]).

The increasing complexity of modern society makes us ever more dependent on expertise ([1]). As outsiders to any domain of knowledge, we are forced to make judgements of credibility and expertise. Even being an expert in one scientific domain (e.g., cosmology) does not make one an expert in another (e.g., evolutionary biology). And though there have long been conspiracy theorists and snake-oil salesmen, the internet and social media have provided a much louder megaphone—and the means to avoid traditional gatekeepers ([5]). The acceptance of unfounded claims—e.g., the idea that vaccines cause autism, that the Earth is flat, or that climate change is a hoax—is of grave concern. For, though true knowledge is a collective good, information that is flawed, or fake, can be a danger—both individually and collectively. For instance, the idea that vaccines are harmful endangers not only the lives of those who hold this idea, but the whole community that depends on a high level of vaccination to ensure its health.

Why people choose to believe flawed or fake information is complex ([6, 7]). Studies in the public engagement with science have shown repeatedly that individuals tend to reject scientific information that threatens their identity or worldview. Nevertheless, the task of a liberal education is to provide individuals with the knowledge required to critically evaluate claims. This is particularly important for young people before their ideologies and identities become entrenched. How they choose to then act is the individual's choice, but the function of education is to provide them with the best tools possible to make informed choices.

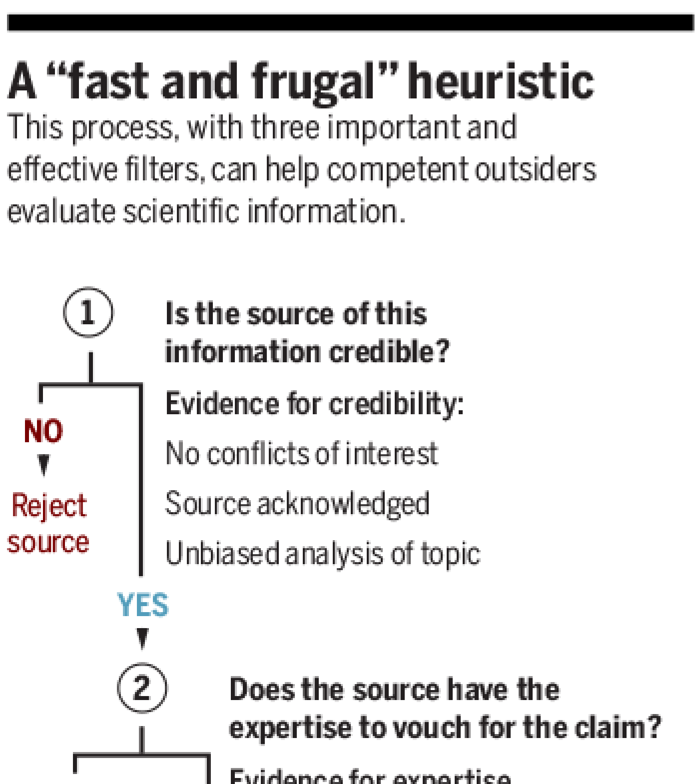
Research in the past 5 years has developed a range of approaches based on "inoculation," "debunking," or "lateral reading" ([2]). Education must, therefore, draw on this body of work if it is to be part of the solution to the challenge of scientific misinformation. Existing curricula, such as the US Next Generation Science Standards, place an emphasis on engaging in scientific practices such as arguing from evidence and analyzing and interpreting data. Although the inclusion of these practices in science education offers a valuable and innovative window into the internal workings of science, they sustain the belief that any individual can evaluate the evidence for themselves. Such a goal is misconceived. Formal science education can never provide all the knowledge that is needed—much less the knowledge that might be required to evaluate the science that is yet to come. Hence, believing that all individuals might be capable of evaluating all scientific evidence for themselves is not a realistic response ([8]).

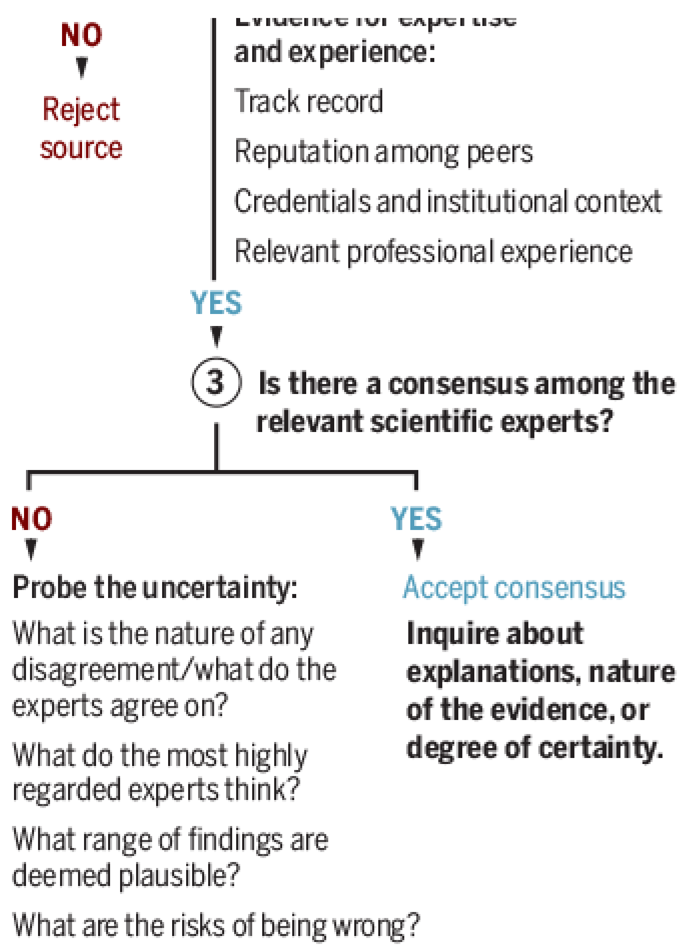
Rather, the goal of science education must be to make "competent outsiders" ([9]) of all students. Every one of us, when lacking detailed knowledge of any scientific topic (including scientists outside their own specialism), requires an understanding of three key concepts to evaluate any scientific claim successfully. These are (i) the social practices that the scientific community uses to produce reliable knowledge ([10]); (ii) the criteria of scientific expertise; and (iii) the basics of digital media literacy. Knowledge of the first two elements is central to developing the competency required to interrogate the trustworthiness of a source and evaluate claims of scientific expertise. It can only be taught in science, yet existing curricula do not offer any explanation of the vital social practices used by science for detecting and preventing error. In particular, neither the importance of consensus in establishing reliable knowledge, nor peer review, even in its narrowest sense, get a mention in K-12 standards. Moreover, these ideas should be addressed in middle school and high school, advanced placement, and undergraduate classes if they are to take hold and never wither.

Why is knowledge of the social practices of science so critical? First, as in the case of the IPCC report, our individual knowledge is bounded. We are all epistemically dependent on experts, whether it be doctors, lawyers, or bridge engineers ([11]). And, when confronted with claims by experts, the central challenge for the competent outsider becomes one of whom to trust. In the case of science, it is a knowledge of the mechanisms that science uses for establishing credibility—the credentials that enable anyone to claim expertise within a discipline and the social practices the scientific community uses to ensure the production of reliable knowledge ([10]).

Our overview of the basic procedures that the competent outsider should adopt (see the figure) is synthesized from a large body of research ([2, 12])—elements of which have been shown to be effective ([13]). The steps outlined in the figure offer a "fast and frugal" heuristic for evaluating scientific information for the competent outsider, capturing the three most important and effective filters—all of which must be applied.

Contrary to the intuitions of many, the first question to teach students to answer is not "what is the evidence?" nor "what are the arguments?" These are questions for those with relevant expertise—the scientists who can recognize sources of error, cherry-picked data, or flaws in the methods. Instead, the first questions the competent outsider must ask are: Is the source of information credible? Is there a conflict of interest? To what extent is the source impartial? Does the author cite their sources of evidence? Here we have much to learn from the recent innovative work on civic online reasoning ([13]). When it comes to the internet, expert fact checkers commonly leave the webpage within 30 seconds. They employ the technique of "lateral reading," opening a new tab in their web browser to research who is making the claim ([13]). Students, by contrast, commonly attempt to evaluate the arguments and evidence on the page itself —a strategy that research shows leaves them none the wiser ([13]). Why? Because the evidence is often partial or picked to support misleading conclusions. Moreover, existing media literacy approaches to evaluating information such as the commonly used CRAAP checklist (Currency, Relevance, Authority, Accuracy, and Purpose) have been shown to be of little value for helping students to detect flawed information. Why? Because (i) these tests do not start by asking about the source's credibility; (ii) the focus on "accuracy" reflects a belief that the individual is capable of evaluating the evidence for themselves; and (iii) such resources commonly use only one of our three essential filters represented in the figure. Yet research shows that students can readily learn some of the basic skills used by fact checkers to improve their performance ([13]).





GRAPHIC: N. CARY/*SCIENCE*

Establishing credibility alone—e.g., whether there are conflicts of interest or political bias—however well done, is not sufficient. Individuals need to understand something about the way science produces reliable knowledge. Thus, having passed the first filter, the second filter for the nonexpert is the question: Does the source have the scientific expertise to make this claim? Just as one would not trust a plumber to fix an automobile engine, why trust a physicist who claims to know about the effect of tobacco on health? Yet the mantra of being a "scientist" has been shown to endow a generic cloak of respectability ([14]). Hence, many scientists have been enlisted to cast doubt on the scientific consensus, even when they have no relevant expertise. Students need to know that science today is a highly specialized activity. Being an expert in one science does not make one an expert in all sciences.

If the source looks credible, the crucial third filter is the question: Is there a scientific consensus on this issue? In the case of climate change, evolution, or the origin of the Universe, the layperson can find that the answer is an unequivocal "yes." In the case of threats posed by new virus variants or the long-term effects of new medical treatments, the answer may be less certain and more equivocal. In such cases, not surprisingly, nonexperts may be confused.

In the absence of a consensus, the competent outsider is well advised to doubt any lone voice who claims to know with absolute certainty ([15]). Scientific consensus is the public benchmark of reliability. Such knowledge is trustworthy because it is the product of extensive empirical work that has been examined critically from many perspectives. Although science-in-the-making may always be open to question, a decisive majority of experts is our best bet of what to trust. Notable exceptions (e.g., Galileo) are memorable because they are just that, exceptions. And, in most cases, dissenting voices turn out to be wrong. Knowing the importance of consensus, naysayers sometimes endeavor to project an alternate one, such as the Leipzig Declaration on Global Climate Change—essentially a "consensus" of nonexperts.

Yet, the knowledge needed to answer our three questions is rarely taught as a component of any science education—nor is it a feature of any teaching of digital media literacy. Even at the undergraduate level, discussions about the social nature of science are often absent. Given its importance then, scientists and science educators have a fundamental responsibility to teach about the social mechanisms and practices that science has for resolving disagreement and attaining consensus.

Undoubtedly, there is still more that the competent outsider needs to know. Peer-reviewed publication is often regarded as a threshold for scientific trust. Yet while peer review is a valuable step, it is not designed to catch every logical or methodological error, let alone detect deliberate fraud. A single peer-reviewed article, even in a leading journal, is just that —a single finding— and cannot substitute for a deliberative consensus. Even published work is subject to further vetting in the community, which helps expose errors and biases in interpretation. Again, competent outsiders need to know both the strengths and limits of scientific publications. In short, there is more to teach about science than the content of science itself.

Science textbooks, however, commonly traffic in the settled "facts" of yesterday's science. Scientific misinformation capitalizes on this feature by appealing to the mythical ideal of science that such textbooks implicitly perpetuate. For instance, detractors may argue that "if scientists can't even predict the weather next week, how can they predict the climate in 100 years?" This impossible standard erodes the cultural authority of science. Uncertainty is an inherent aspect of science, particularly for science-in-the-making. Teachers of science must acknowledge that uncertainty is normal and show how science has evolved standard ways to address or minimize it. This can be done just by getting a class to measure the length and breadth of a piece of paper, or the temperature in the room, and then asking what is the most accurate answer.

Science curricula that exist across the globe today, however, were written for a different era—one in which misinformation could not be circulated at the speed of a “retweet.” The threat to science from this new facility to disseminate misinformation so readily is, we argue, akin to the challenge posed by the launch of Sputnik in 1957. Likewise, it needs a similar coordinated response by scientists to acknowledge its importance. How the scientific community produces reliable knowledge is essential knowledge for a competent outsider. Such an omission from education—be it formal or informal—not only fails our future citizens but also fails science itself.

There are at least four contributions that education can make to address scientific misinformation: adapting teacher training; developing curricular materials; revising standards and curricula; and improving assessment. The last of these is the most powerful and immediate lever. Assessments can be high stakes for both teachers and students. Hence they are read carefully as an important signal of the intent of the curriculum. The Programme for International Student Assessment (PISA) for 2025 will be innovative, as it will assess 15-year-old students’ competence to “research, evaluate and use scientific information for decision making and action…and evaluate its credibility, potential flaws and the implications for personal and communal decisions.” Asking students to identify the dubious nature of a scientific claim or the cherry-picked nature of the data represents a gestalt shift in assessment that commonly focuses on reproducing the right answers. However, it is readily achievable—it is just not something that examiners are used to doing.

Developing new curricula and materials is already underway, such as by the program on Civic Online Reasoning at Stanford University, and efforts in Finland, Israel, and elsewhere. For example, exercises can be used by students to evaluate claims made by different websites ([4]), such as co2science.org, which makes many misleading claims about climate change. Using “lateral reading,” students will find that this website has received funding from ExxonMobil, providing an opportunity to discuss conflicts of interest in science. Checking the “About Us” section, students will find only two staff listed, one of whom was the chair of the “Nongovernmental International Panel on Climate Change (NIPCC).” Further research shows NIPCC to have been supported by the Heartland Institute, a lobbying group set up to oppose the reports of the IPCC. This exercise would then afford opportunities to discuss what constitutes relevant expertise in science. In addition, a search for what the scientific consensus is on climate change reveals that 99% of scientists would disagree with the claims made on this website.

As for science standards, these are established at the country level or—in federal societies such as the United States, Germany, or Canada—at the state level. The problem is that most of these, including the influential Next Generation Science Standards, were drafted a decade ago before the current maelstrom of social-media–fueled misinformation swept the globe. In principle, they espouse the goal of educating students to be scientifically literate but commonly fail to define what such an outcome might look like, or what a student might be able to do as a result of such an education. Rather, what these standards tend to offer is a window into the internal workings of science. Although there is nothing wrong with that, it is inadequate if students are to become "competent outsiders." Those who sit on the committees that draft these standards must recognize and address these weaknesses. Revising curriculum standards is the responsibility of scientific societies and academies, science teacher organizations, and science educators, all of whom need to take up the baton and address this issue through their existing structures. However, achieving such change can only be a medium-term goal.

Transforming preservice teacher training is a long-term goal. First, there is no uniform professional path to becoming a teacher of K-12 science, and neither are there any commonly agreed goals for training. Teacher training is ultimately responsive to what it sees to be the priorities in the standards and in the classrooms for which it prepares its students. Where others lead, it will follow.

It is time for scientists and science educators to step up to help address the complex problem posed by the plague of misinformation. Given that education standards define what knowledge counts, the primary goal must be to achieve a transformation in the limited curricula that students currently experience. More generally it means that all of those endowed with the label of being a scientist must accept the responsibility to explain why the fruits of their labor should be both valued and trusted.

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REFERENCES AND NOTES

1. T. Nichols, *The Death of Expertise: the Campaign Against Established Knowledge and Why it Matters* (Oxford Univ. Press, 2017).

2. A. Kozyreva, S. Lewandowsky, R. Hertwig, *Psychol. Sci. Public Interest* **21**, 103 (2020).

3. S. Vosoughi, D. Roy, S. Aral, *Science* **359**, 1146 (2018).

4. J. F. Osborne *et al., "Science* Education in an Age of Misinformation," Stanford University, 2022.

5. D. Höttecke, D. Allchin, *Sci. Educ.* **104**, 641 (2020).

6. D. Kahan, H. Jenkins-Smith, D. Braman, *J. Risk Res.* **14**, 147 (2011).

7. S. Lewandowsky, K. Oberauer, *Curr. Dir. Psychol. Sci.* **25**, 217 (2016).

8. L. Gierth, R. Bromme, *PLOS One* **15**, e0231387 (2020).

9. N. Feinstein, *Sci. Educ.* **95**, 168 (2011).

10. C. Z. Elgin, *True Enough* (Harvard Univ. Press, 2017).

11. J. Hardwig, *J. Philos.* **82**, 335 (1985).

12. S. Lewandowsky, S. van der Linden, *Eur. Rev. Soc. Psychol.* **32**, 348 (2021).

13. S. Wineburg *et al., J. Educ. Psychol.* **114**, 893 (2022).

14. N. Oreskes, E. M. Conway, *Merchants of Doubt* (Bloomsbury Press, 2010).

15. B. Russell, *Sceptical Essays* (George Allen & Unwin, 1928).

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