# Tackling Scientific Misinformation in Science Education

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## Introduction

The goal of science is the production of reliable and trustworthy knowledge [1, 2]. The spread of scientific misinformation, and in some cases scientific disinformation, poses a serious threat which undermines that project and all the work of scientists, educators, and users of science [3-6]. For this reason, scientists and science educators are deeply concerned about scientific misinformation, which, at its worst, can lead to harm. For example, a report commissioned by the Carnegie Corporation of New York noted that, "Resistance to masking and vaccines [during the pandemic], based largely on misinformation (and disinformation), almost certainly cost hundreds of thousands of lives" [7].[1] In response, the National Academies established a panel to consider how to understand and address misinformation about science.[2] Likewise, the Nobel Foundation held a summit on "Countering Misinformation and Building Trust in Science."[3]

Yet, there has been little consideration to date of what might be done in K-12 education, where most people acquire their foundational knowledge about science [8-10]. This paper argues that addressing the issue of misinformation in formal science education is a critical contribution that society can make. It does this by offering a rationale for teaching K-12 science students the basic knowledge and competencies needed to evaluate the *credibility of sources* of information about science and technology. Future citizens will be confronted by science that is likely to be way beyond anything they might have learned in school. Hence, as they cannot evaluate the science itself, they must learn how to evaluate the trustworthiness of the source.

Our analysis of the problem and our recommendations are informed by the discussions at a conference held at Stanford University in early February 2023. Twenty science educators and media literacy experts convened for two days to discuss current science education standards in the United States and how they might be leveraged to address several

[1] Misinformation is found in many forms, including conscious attempts to lie or mislead people, which is often identified as disinformation.

[2] https://www.nationalacademies.org/our-work/understanding-and-addressing-misinformation-about-science

[3] https://www.nobelprize.org/events/nobel-prize-summit/2023

concerns, especially the increasingly harmful influence of scientific misinformation [11]. The group included individuals closely connected to the Next Generation Science Standards (NGSS) [12], representatives from the National Science Teaching Association and the Council of State Science Supervisors, major national curriculum development groups, funding agencies, public broadcasting, and a leader in media literacy education efforts. Other individuals came from local, district, state, national, and federal entities (a full list is in the Appendix).

The NGSS emphasize teaching eight science and engineering practices, including the practice of "obtaining, evaluating, and communicating information" about science and technology (Practice 8). However, in its current form this practice neither addresses the challenge of scientific misinformation sufficiently nor articulates what might be reasonable outcomes that would demonstrate competency at distinguishing between more and less reliable sources of information. And, given that most state standards for science are closely aligned with the NGSS, this weakness is a national issue.

Few people believe that now is the time to rewrite the standards; many states, curriculum developers, and teachers are still coming to terms with developing their teaching approaches, supporting materials, and assessments. However, the problem of scientific misinformation is too important to wait for standards to be rewritten; something must be done now to develop in students the basic competencies required to help them detect what is true and what is false or misleading. An important starting point for teaching young people to resist scientific misinformation, therefore, is Practice 8, as its essential goal is to develop a student's ability to judge the credibility of scientific information.

In the remainder of this paper, we first elaborate why scientific misinformation has become such a significant problem and how teachers can help young people become better judges of allegedly scientific information. Then we discuss how existing science education standards can better support instruction about misinformation and the materials that will be needed. Finally, we argue that it is both appropriate and timely to bring together organizations in science education as an Alliance for Scientific Media Literacy Education committed to addressing the problem.



## The Challenge of Scientific Misinformation

While true knowledge is a public good, flawed, false, or misleading information can be a danger—both individually and collectively. For example, developing a response to the challenges of climate change has been slowed in the United States by mis- and disinformation [13]. The scientific slant of so much misinformation represents a serious threat to all the sciences and a danger to the ways our society produces reliable knowledge of the natural and material worlds.

Since the development of the NGSS standards in 2012, pervasive use of the internet has changed the societal context dramatically, giving purveyors of misinformation both a means of avoiding traditional gatekeepers and a much louder megaphone. Today, young people are more likely to get their information from YouTube and Tik Tok than from conventional media [14]. While some channels on these platforms are trustworthy sources of information, many are not. Students are then forced to judge the credibility of the information and its source. Contrary to the common conception that young people are fluent digital natives, the research evidence shows that they struggle to avoid deception [15, 16].

In addition, much of the scientific misinformation confronting the public lies beyond anything addressed by K-12 science education. Thus, the issue of evaluating a scientific claim becomes one not of judging the validity of the evidence but of evaluating the credibility and trustworthiness of the source.

The issue, as aptly identified by Helen Quinn, chair of the committee that drew up the K-12 framework for the NGSS standards, is that "I can find lots of information on my phone, some of it is good, some of it is not. How do I know? And what do I do to figure out what's reliable and what's not? That's a skill we need to be teaching because it's a critical skill for democracy, too" [17].

Until a decade ago, editors in the mainstream media had a major role in determining the availability and accuracy of news and other sources of information. In contrast, in today's world anyone can publish information that becomes available instantly to millions of people. About 86% of Americans receive their news from online sources, more than from any other medium [18]. While 46% of teens report that they are online "almost constantly" [14] where misinformation is common: whether it is spread inadvertently via social media; or by people and organizations that care primarily about getting attention, rather than accuracy; or by those who do so with the express intent of sowing doubt about science [19]. Moreover, misinformation online gets considerable attention. By 2016 the top 20 fake stories on Facebook received many more views than the top 20 real news articles [20].

Science education standards acknowledge the importance of learning to use science in everyday decision-making, including in societal and personal contexts where people need to apply science (e.g., voting for candidates, purchasing products, making health-related decisions), but there is an implicit assumption that a K-12 science education based on the NGSS standards will enable individuals to evaluate scientific evidence for themselves, even on topics that were not part of the curriculum. However, in a great many cases that is not true. For example, few people understand how vaccines work, how they are developed, and the evidence that they are safe; most people are not able to obtain and evaluate scientific data accurately about those matters by themselves nor to identify incomplete or biased evidence. Much of the science that informs decision-making at personal, local, and global levels—from decisions about nutrition and health to the environmental effects of deforestation—is complex and only understandable by experts. If the science is beyond them, the issue for the public is one of credibility and of whose advice can be trusted.

Therefore, a major responsibility of school science education is to educate students to be "competent outsiders" to science [21]—that is, individuals who are able to judge the credibility of scientific claims as educated non-experts. These are people who, while lacking the expertise to obtain, read, or evaluate the evidence for themselves, have sufficient knowledge of the key features of science, including its social practices, that enable scientists to produce reliable and trustworthy knowledge. Rather than trying to weigh what is often complex and detailed scientific and technological evidence (as in IPCC reports about climate change), such non-experts should focus their attention on evaluating the credibility and trustworthiness of the information sources. This, after all, is what we do when choosing a plumber, a lawyer, or a doctor. Developing the capability needed to judge the credibility of information sources has



become so important that it is the focus of a new competency in the 2025 OECD PISA framework to be used in international student assessments: "Research, evaluate, and use scientific information for decision making and action" [22].

What then are the capabilities and knowledge required of a "competent outsider" or non-expert? And how could NGSS Practice 8 be unpacked to develop student competencies to: better recognize scientific misinformation; enlarge teachers' understanding of that topic; and promote the teaching of knowledge and capabilities needed to resist misinformation?

## Identifying Scientific Misinformation

Despite growing up in a digital environment, research shows that students have considerable difficulty evaluating the credibility of sources of information on the web [23, 24]. For instance, after working with hundreds of students, a group at Stanford found that 96% of students did not recognize that ties between the fossil fuel industry and a website claiming to provide accurate information about climate change might pose a problem for that website's credibility.

However, recent research and expert opinion suggest there are multiple approaches that will help develop student competency at identifying scientific misinformation [25]. Moreover, a growing body of experimental findings show that these interventions will improve people's capacity to evaluate sources of information (e.g., [26, 27]).

One basic approach called "lateral reading" has proven effective at improving student resistance to misinformation [23]. Lateral reading focuses on answering the question, "Is this source credible?" The answer will not be found by reading the webpage or claim itself. Rather, the user must open another browser tab or window to ask what is known about the individual or the institution making the claim to see what their conflicts of interest or potential biases might be. For instance, doing this for the website "CO2science.org" reveals that it is funded by Exxon Mobil. This basic skill has been shown experimentally to facilitate a student's ability to judge the credibility of information sources and the claims they make [23]. In short, to help evaluate a claim on the internet, students must learn to first consider: why the information is there (e.g., to provide important information, to sell a product, to challenge other existing claims); whether the source has an obvious conflict of interest (e.g., they are providing information for an interested party which is not acknowledged); and whether the provider of the information has a reputation for dishonesty.

In addition to more general capabilities, such as lateral reading, students need some knowledge that is specific to science. Is the information source a person or group with recognized expertise in the science which is the focus of the claim? Is there a scientific consensus on the topic? Answering these questions calls for a greater understanding of the social practices that are specific to science, especially how scientists reach a consensus, including the role that the scientific community and scientific institutions play in that process [11]. And claims made by those with a demonstrable conflict of interest or by those who lack expertise in a field should be regarded with a high level of skepticism. Likewise, claims that challenge a well-established scientific consensus should be regarded with suspicion.

For students to become better judges of sources of scientific information it is essential that they learn that being an expert in one scientific discipline does not make you an expert in another, let alone in all sciences. For example, Linus Pauling, winner of two Nobel Prizes, wrote articles and popular books on the therapeutic powers of Vitamin C—an erroneous claim accepted by many. This claim boosted sales of Vitamin C but was later debunked by experts in health and medicine, which Pauling definitely was not. Likewise, the tobacco and oil industries have made extensive use of scientists to cast doubt on the arguments of experts, even though those scientists had no expertise in that field [19].

Moreover, to become competent outsiders, students need to know that, fundamentally, "science is a social process" and has a well-established mechanism for vetting claims and weeding out flawed research and dubious evidence [28, 29]. This is the continuing process of peer review, in which critical examination by other experts is normally required before research is funded, presented to other scientists, published, and then used by other scientists in the field.

Furthermore, students need to learn that individual research efforts are seldom sufficient to establish scientific consensus, particularly in complex fields such as climate change, the safety of vaccines, or treating diseases. Reaching consensus typically requires multiple research efforts, often across multiple scientific disciplines, and commonly over many years. If there is no consensus, then there will be competing arguments, and this is a sign of a healthy scientific community and not something that can be used to deny the value of scientific findings or work.

Key institutions are vital in helping to establish if there is a consensus. For example, the National Institute of Medicine commissioned 18 highly qualified experts in immunology to review the safety to children and adults of 8 vaccines. This review determined that, with rare exceptions, those vaccines are very safe, based on evaluating results of *hundreds* of peer-reviewed studies [30]. What is true in this instance, is true of all knowledge based on a scientific consensus. For, when scientists reach a consensus, their knowledge is typically based on evidence gathered by multiple researchers that is evaluated, compared, combined, and communicated through scientific meetings, meta-analyses, and syntheses under the auspices of expert groups, such as the CDC, FDA, and IPCC. One specific role of such institutions is to determine and represent any scientific consensus that exists to provide reliable scientific knowledge.

Because misinformation was not such a grave threat when the NGSS were developed teaching these features of science was not a high priority. Given the flood of scientific misinformation that has emerged in the past decade, the authors' view is that the NGSS' practice of "obtaining, evaluating, and communicating information" needs elaboration and support if such teaching is to better help students distinguish between credible information and misinformation.

## Improving the Explanation of NGSS Practice 8

We believe the science education community should recognize that the competencies identified above must be an explicit part of what it means to "obtain, evaluate, and communicate" scientific information. In turn, that requires clarifying and explaining what kinds of tasks students should be able to do by grades 5, 8 and 12. Minimally, this unpacking of Practice 8 needs to point to key disciplinary knowledge required by claimants, and how peer review and consensus-building, based on multiple research studies, lead to the development of reliable and trustworthy scientific knowledge. The role of key scientific institutions as sources of reliable knowledge also needs to be taught.

NGSS Appendix F describes in some detail expected outcomes associated with Practice 8, such as (for grades 9–12): "Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source." Students need help in, for example, how to identify "authoritative sources." They should also learn that to "assess the evidence," they need to judge whether they have sufficient knowledge to make such an evaluation. If not, they should, in the first instance, apply the tests suggested above to check for conflicts of interest, relevant expertise, and whether a scientific consensus exists. Instructional materials that support the teaching of this practice would be extremely helpful to teachers.

To accomplish this unpacking of the NGSS Practice 8 to better support teaching about scientific misinformation, a developmental framework will be needed that explains the knowledge and skills that should be taught and learned in each grade band.

Some useful curriculum materials already exist that focus on scientific misinformation. *Misinformation Nation*, for example, is a series of four short videos from PBS NOVA, free online from PBS Learning Media, that can be used "to help prepare students to be critical consumers of science content and to make informed judgements about the science media they encounter." Several professional journals for teachers have published lesson plans for teaching about misinformation in science.[4] Other approaches have been developed for use with the public [3].

However, what is missing are: a more systematic attempt to examine how the issue of scientific misinformation can be addressed through science education; identifying the basic and more advanced competencies and how they can be developed at each grade band.

[4] Examples include https://www.nsta.org/science-teacher/science-teacher-january-2020/just-say-no and https://doi.org/10.1525/abt.2020.82.6.429



## The Response

Science teachers alone cannot be expected to address this challenge themselves. Dealing with the scourge of scientific misinformation requires a systemic response from a range of stakeholders. If these arguments are accepted, then what must be done?

### *Ensuring that Scientific Misinformation is addressed by NGSS Practice 8*

We cannot express too strongly what a threat misinformation, much of which is scientific, poses to a well-ordered and democratic society. At a minimum, we argue that science education must make the contribution identified in this document to enhancing student capabilities to undertake what lies at the core of Practice 8—obtaining and evaluating *credible* information, even about topics they have not studied. This will require a group of knowledgeable stakeholders to revisit the current instantiation of Practice 8 and to look at how it can be communicated and easily implemented by teachers and other science educators.

### *Identifying and Developing More Instructional Materials*

Many countries are now developing national approaches to media literacy education and there are a range of resources.[5] However, no systemic attempt has been made in the United States to develop materials about misinformation for K-12 *science* educators. Improving the teaching of Practice 8 will depend on the ready availability of instructional materials that develop a student's capability to distinguish credible scientific information from misinformation. Funding to support their immediate development is an urgent priority. Research is also needed about their best use and efficacy. To help teachers, a web-based catalog of high-quality materials about misinformation should be made available, indexed to different grade levels and science subjects.

[5] https://ctrl-f.ca/; https://faktabaari.fi/edu/oppaat/; https://cor.stanford.edu/curriculum/collections/cor-for-the-science-classroom/

*Obtaining Support from the Scientific and Science Education Community*

The case for the importance of addressing scientific misinformation in K-12 education cannot depend on a few lone voices in the wilderness. It requires the full and unequivocal support of those professional bodies that represent both the scientific and the K-16 science education communities. An important step would be the development of position statements and editorials that recognize the threat posed by scientific misinformation and the need for it to be addressed systemically in schools and undergraduate education.

*Developing Systemic Capabilities*

Helping students reject misinformation is a responsibility to be shared across multiple subjects. At the same time, teaching students how to distinguish trustworthy science from the misinformed or deliberately disingenuous is a fundamental responsibility of science teachers, who are the representatives of science in the classroom. To help them undertake this role, they need to be provided with both pre-service and in-service professional development. Likewise, assessment systems, such as the National Assessment of Educational Progress, College Board examinations, and state testing systems need to signal its importance by developing exemplary assessments of the kinds of performance it would be reasonable to expect at each level.

This work would be better informed if there were more research investigating how teachers address the issues in grades K-5, 6-8, and 9-12. Topics such as how scientists build consensus are complex and need attention at multiple grade levels and from a variety of perspectives.

## The Way Forward

The health of liberal democracies depends on access to trustworthy and reliable knowledge in all disciplines. Such knowledge informs both our personal and societal decision-making and actions. As a major source of such knowledge, science is seen as both



an authoritative provider of reliable knowledge and as a vital source of solutions to many of our contemporary challenges. Information that is misinformed or simply wrong is a threat to the health, vitality, and morale of all our communities. Although schools alone cannot overcome all the known problems of increased polarization, or uncover all sources that deliberately lie or mislead, nonetheless education has a vital role to play in helping young people to develop the basic competencies required of a non-expert to identify misinformation.

We are not alone in believing that the problem of scientific misinformation is too important to wait. Nor are we alone in believing that an alliance of key stakeholders is needed to promote the teaching of media literacy that addresses scientific misinformation in K-16 science classes. Efforts are underway to advance this work under the leadership of Media Literacy Now, a non-profit with years of experience in multiple states.

Our essential argument is that education, and science education in particular, has a fundamental responsibility to address this challenge and to develop a competency in the general public to distinguish credible scientific information from misinformation.

Our plea is that the relevant scientific institutions, science educators, and other stakeholders must recognize collectively the urgency of this threat and address the issue in the ways we suggest. To do nothing will simply erode the trust that good science deserves.

# Appendix

The following is a list of conference participants.

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| Douglas Allchin | Fellow, University of Minnesota |
| Ralph Bouquet | Director of Education and Outreach for PBS NOVA |
| Marjee Chmiel | Director of Evaluation for science education and media, HHMI |
| Katie Coppens | Science teacher, Falmouth Maine |
| Chad Dorsey | President and CEO, the Concord Consortium |
| Daniel Edelson | Executive Director, BSCS Learning |
| Michael Ford | Program Director, NSF |
| Linda Hooper | Associate Director for Assessment, California Dept. of Education |
| Natalie King | Associate Professor, Georgia State University |
| Michael Lach | Assistant Superintendent, Township H.S. District 113 |
| Erin McNeill | Founder and President, Media Literacy Now |
| Penny Noyce | Founder and CEO, Tumblehome Books |
| Brian Reiser | Professor, Northwestern University |
| John Rudolph | Professor, University of Wisconsin-Madison |
| Megan Schrauben | MiSTEM Network Executive Director, Michigan |
| Jennifer Self | Science Review Lead, NextGenScience, WestEd |
| Erika Shugart | Executive Director, NSTA |
| Jonathan Osborne | Professor Emeritus, Stanford University and Organizer |
| Andy Zucker | Independent Scholar and Organizer |
| Daniel Pimentel | Organizer |



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