UNESCO Recommendation on Science and Scientific Researchers and the United States

An Analysis of Key Themes

August 2022

Jessica Wyndham, Nathaniel Weisenberg, Catherine A. McCarty, Gretchen T. Goldman, Matthew Brown, and Jason Borenstein

AAAS | Scientific Responsibility, Human Rights and Law

Acknowledgements

This report was authored by:

Jessica Wyndham (Program Director, AAAS Scientific Responsibility, Human Rights and Law Program[1])
Nathaniel Weisenberg (Senior Program Associate, AAAS Scientific Responsibility, Human Rights and Law Program)
Catherine A. McCarty (Associate Dean of Research, University of Minnesota Medical School, Duluth)
Gretchen T. Goldman (Research Director, Center for Science & Democracy, Union of Concerned Scientists[2])
Matthew Brown (Director, Center for Values in Medicine, Science, and Technology, The University of Texas at Dallas)
Jason Borenstein (Director of Graduate Research Ethics Programs, Georgia Institute of Technology)

Disclaimer

---

[1] Jessica Wyndham's role as co-author of this report took place when she was Program Director of the AAAS Scientific Responsibility, Human Rights and Law Program, a position from which she resigned in December 2021. Her continued involvement in this work has been in an individual capacity.
[2] Goldman contributed to this report during her time at the Union of Concerned Scientists, from which she went on leave in July of 2021. Her continued involvement in this work has been in an individual capacity.

AAAS served as the facilitator of this report. The opinions, findings and conclusions or recommendations expressed in this publication do not necessarily reflect the views of the authors' home institutions.

Contact

The authors welcome comments and questions regarding their work. Please send information, suggestions, and any comments to Nate Weisenberg (nweisenberg@aaas.org).

Cite as

Wyndham, J., Weisenberg, N., McCarty, C., Goldman, G., Brown, M., and Borenstein, J. 2022. *UNESCO Recommendation on Science and Scientific Researchers and the United States: An Analysis of Key Themes*. https://doi.org/10.1126/aaas.ade8203

Table of Contents

Introduction

UNESCO Recommendation on Science and Scientific Researchers

On 13 November 2017, the 39th General Conference of the United Nations Economic, Social and Cultural Organization (UNESCO) adopted the Recommendation on Science and Scientific Researchers (2017). The Recommendation is a non-binding document that is intended to codify the goals and values by which science and scientists should operate. It also articulates how these need to be supported and protected through national science, technology, and innovation policies and infrastructure. Finally, the Recommendation addresses how the knowledge generated by science in all fields should be applied.

The Recommendation supersedes an earlier version that dated back to 1974. The motivation for revising the 1974 document was to "reflect the contemporary ethical and regulatory challenges relating to the governance of science and science-society relationship." Among the contemporary issues that UNESCO recognized as needing to be incorporated into the updated Recommendation were gender equity, public participation in science, the internationalization of research, new methods for dissemination of scientific information, and the growing dominance of industry and commercial enterprises in science (AAAS, 2014).

UNESCO has developed a summary of the Recommendation, distilling the content of the Recommendation into "10 key areas." According to this summary, the Recommendation:

1. underlines the responsibility of science towards the United Nations' ideals of human dignity, progress, justice, peace, welfare of humankind and respect for the environment;
2. emphasizes the need for science to meaningfully interact with society and vice versa;
3. recognizes the role of science in national policy and decision-making, international cooperation and development;
4. promotes science as a common good;
5. calls for inclusive and non-discriminatory work conditions and access to education and employment in science;
6. emphasizes that any scientific conduct is subject to universal human rights standards;
7. balances the freedoms, rights and responsibilities of researchers;
8. calls for scientific integrity and ethical codes of conduct for science and research and their technical applications;
9. recognizes the vital importance of human capital for a sound and responsible science system; and
10. stresses the role of Member States in creating an enabling environment for science and research.

A significant addition in the 2017 Recommendation is the inclusion of a reporting mechanism. Every four years, the UNESCO Secretariat is charged with collecting information from UNESCO Member States and other relevant partners, to use the information gathered to monitor

implementation of the Recommendation, to identify good practices, and suggest steps to improve implementation.

The Recommendation and the United States

UNESCO was created in 1945 for the purpose of contributing to "peace and security by promoting collaboration among the nations through education, science and culture." States that are members of the United Nations (UN) are eligible to also become Members of UNESCO.

The United States (U.S.) joined UNESCO at its founding. Indeed, Archibald MacLeish, a U.S. member of UNESCO's governing board at the time, wrote the preamble to the UNESCO Constitution. In 1984, however, the U.S. withdrew from the organization because of what is described by the U.S. State Department as "a growing disparity between U.S. foreign policy and UNESCO goals" (State Department, 2011). The U.S. rejoined the organization in October 2003. In announcing the decision to rejoin UNESCO, President George W. Bush stated, "As a symbol of our commitment to human dignity, the United States will return to UNESCO. This organization has been reformed and America will participate fully in its mission to advance human rights and tolerance and learning" (State Department, 2011).

In 2011, when UNESCO elevated Palestine to Member status, the U.S. under the Obama administration stopped paying its membership dues to UNESCO in protest. In 2017, Rex Tillerson, then Secretary of State under President Trump, announced the decision to withdraw from UNESCO and that decision came into effect on 1 January 2019. In total, 193 countries are currently Members of UNESCO. The United States remains outside the organization.

The United States was a member of UNESCO at the time of the review and revision of the Recommendation (1974). As part of the General Conference, the United States voted in favor of adoption of the Recommendation. Because the United States is not currently a Member of UNESCO, however, it is not bound by the reporting requirements of the Recommendation. Nonetheless, the UNESCO Recommendation articulates global standards that can serve as a guidepost for the U.S. scientific community, for policy makers, funders, and scientists themselves. It is in that spirit that the American Association for the Advancement of Science (AAAS), with leadership and guidance from UNESCO together with a European consortium of institutions committed to responsible research and integrity, undertook a preliminary review of implementation of the Recommendation in the context of the United States.

Process and Scope

AAAS is the world's largest multidisciplinary scientific membership organization and publisher of *Science* and the *Science* family of journals. The organization seeks "to advance science, engineering, and innovation throughout the world for the benefit of all people." Goals it pursues in fulfillment of that mission include promoting and defending the integrity of science and its use, promoting the responsible use of science in public policy, strengthening and

diversifying the science and technology workforce, and increasing public engagement with science and technology. It is within that context that AAAS became part of RRING—Responsible Research and Innovation Networked Globally. RRING, which is funded by the European Union, aims to make research and innovation systems everywhere more responsible, inclusive, efficient, and responsive as an integral part of society and economy. RRING is supporting initial efforts to monitor implementation of the Recommendation through several case studies, including in the U.S.

The goal of the process was to assess the U.S. scientific enterprise as it relates to the UNESCO Recommendation on Science and Scientific Researchers. Given that the U.S. is not a Member of UNESCO, this report is not an official report but could serve as a model for U.S. consideration of its policies and practices with regard to science and scientific researchers, with the potential to inform similar assessments in the future in the event that the U.S. rejoins UNESCO.

The report development process began in September 2020, with a consultative meeting of 19 individuals drawn from academia, civil society, industry, and government. Those invited to join the consultative meeting were asked to join based on their knowledge of and/or experience in addressing scientific responsibility. Meeting participants received an introduction to the Recommendation and were given the opportunity to familiarize themselves with the ten key areas for monitoring the Recommendation. The goal of that meeting was to begin to narrow the focus from the ten key areas to identify those most salient in the U.S. We also aimed to identify a Drafting Group whose task it was to draft this report by gathering and analyzing the data necessary to substantiate conclusions in the report. It was our intention that the Drafting Group have broad representation among the stakeholder groups participating in the consultative meeting.

During the consultative meeting, participants were asked: What are the three top things you would change about the U.S. scientific enterprise today if you could? The following word cloud illustrates the responses given.

Figure 1.

Following lengthy and detailed discussion, the group coalesced around four clusters of topics of particular importance to the scientific enterprise in the United States relating to responsible research and innovation:

1. Equity, diversity and inclusion;
2. Politicization of science, science-based decision making, political pressure in and on science;
3. Science for society, public engagement in science, social impact of science, trust, and science communication; and
4. Ethics, integrity, reproducibility, and bias.

The approach to be taken in this report was always intended to be one driven by data. As a result, the consultative group considered the data that were currently available to elucidate their concerns as articulated in Figure 1. Responses included the following:

- "scientists do not look like population at large";
- "political manipulation of science";
- "relatively low percentage of women/persons of color in STEM (at least in some fields)";
- "surveys of misconduct";
- "lack of reproducibility in publications";
- "peer review process for scientific publication is lengthy, biased. A paradigm shift needs to happen"; and
- "extreme polarization around climate science, vaccines, race, gun control."

Finally, considering any data gaps, participants were asked to suggest additional tools that could be used to collect data relevant to the concern they raised. Examples included the following:

- "Network analysis";
- "Faculty surveys and case studies";
- "Common tools for institutional reporting of integrity issues"; and
- "Survey of journal editors and their biases."

From among consultative meeting participants, six experts volunteered to contribute to draft the report, together with two members of AAAS staff. Due to reasons beyond their control, two of the experts had to pull out before drafting began. The experts and staff identified among the topics highlighted by the consultative meeting participants those in which they had expertise and wanted to serve as lead author. A template structure was prepared for each section, emphasizing the section or sections of the UNESCO Recommendation of relevance to the specific topic, the data available to address the topic, an analysis of those data, and recommendations directed primarily to the government. The reason for the government focus is the multilateral context of the UNESCO Recommendation and because, if the U.S. rejoins UNESCO in the future, any report submitted by the government in accordance with the Recommendation's reporting mechanism would similarly be focused on government policies and programs.

Following the completion of a full draft report, the consultative group reviewed the document, identifying additional topics for inclusion and making suggestions for edits to both the body of the text and recommendations. An additional co-author joined the drafting group bringing expertise in some of the areas identified. That revised document was then reviewed again by the consultative group, and by additional staff at AAAS with expertise in discrete topics addressed in the report, before being finalized and disseminated.

Scope

This report does not aim to address every topic included in the UNESCO Recommendation. Rather, the report offers a snapshot of some of the more pressing areas for attention in the current U.S. context as identified by the consultative group. Furthermore, in the course of its process, the drafting group identified that several of the key topics highlighted by the consultative group were of relevance to a number of the UNESCO Recommendation provisions and that the "10 key areas" did not always address discrete topics but overlapped in significant measure. Finally, several of the topics identified by the consultative group as being of importance suffer from an almost complete or relative dearth of data. The result is that some of the topics addressed draw from a wealth of rich data and others reflect a greater reliance on literature and commentary.

Finally, in this report, the authors use the terms "science," "scientist" and "scientific" to encompass the life, physical, behavioral and social sciences, as well as mathematics and engineering.

Recommendations

As a general recommendation addressed to the government, but also interested academics and scientific organizations, we propose the following:

1. identify the data necessary to establish benchmarks and measure progress in each of the key areas of the UNESCO Recommendation; and
2. establish mechanisms for addressing any current data gaps.

Context

The preparation of this report occurred during an administration that was unprecedented in its overt attacks on science and scientists. Drafting began immediately before a national election that resulted in a change of administration, during a global pandemic, and amidst the largest protests for racial justice in generations. As such, science and scientists, their role in society, the trust that society has (or does not have) in science, and the role and responsibilities of scientists in meeting societal challenges were recurring themes in the national discourse.

In 2018, the Union of Concerned Scientists conducted an analysis of the forms and breadth of political interference in science and science policy over the course of multiple government administrations of both parties dating back to the 1950s. While recognizing the ebbs and flow of government interest in, fidelity to and support of science over this period, the analysis concluded that "the Trump administration's actions reflect a new evolution and escalation of patterns we have already seen. In some cases, the administration's actions can be considered unprecedented" (Berman & Carter, 2018, p. 18). One significant and direct by-product of these actions has been the galvanizing of the scientific community to advocate and to engage more actively in policy fora (Fisher, 2018). That engagement has not only been directed toward government, but also inwardly.

The broad social movement encapsulated by the hashtag #MeToo sparked #STEMToo (STEM = science, technology, engineering and mathematics) discussions about gender-based harassment in STEM and what should be the role of the scientific community and scientific establishments in response, including within universities, disciplinary societies, and among other leading voices in the scientific community. Similar conversations were sparked in 2020 when the diversity conversation within the scientific community expanded to shed light on systemic racism. Initiatives such as #ShutDownSTEM called for action to eliminate systemic anti-Black racism in the sciences, and highlighted the unequal access to scientific education and employment for women and members of minority groups. It is inevitable that the content of this report was crafted through these contextual lenses.

1. Science and Society

Public engagement in science

The UNESCO Recommendation

Public engagement in science can mean different things and take multiple forms. The UNESCO Recommendation recognizes that all members of the public should have an equal opportunity to receive "initial education and training needed to qualify for research and development careers" (Recommendation III, 13(a)). Scientists are viewed as having a responsibility to enhance "their fellow citizens' well-being" (Recommendation IV, 16(a)(iv)). The public are recognized as investing in science through taxes that serve as an important source of funding for research, just as "public trust and support for sciences throughout society" (Recommendation II, 5(c)) are acknowledged as being vital to a robust scientific ecosystem. Access by the public to the results of science is recognized as vital (Recommendation IV, 16(a)(v)).

A significant element of public engagement in science that is not emphasized within the Recommendation but which forms an important component of "public engagement" is public participation in science, that is, engagement of individuals and/or communities in the doing of science, from contributing to the articulation of research questions to helping formulate research design to participating in the research itself. As such, the conceptualization of "science" reflected in the Recommendation is one narrowly defined as involving formally trained scientists to the exclusion of "citizen scientists." In contrast, General Comment 25 of the UN Committee on Economic, Social and Cultural Rights in its elaboration of the meaning of the right to science recognizes as a core component of the right citizen participation in scientific activities (United Nations, 2020). Recommendation IV.20(c) recognizes such citizen participation in a strictly limited context—international research involving human subjects—in the context of which the Recommendation recognizes the value of communities concerned with the subject matter of the research participating in collaborations to define the benefits of the research and access the results.

Given the significance of citizen science as a still emerging area of scientific practice, and the multiple benefits of citizen science, including to improve science literacy (Bonney et al., 2015), it is that element of public engagement in science that is the focus here.

A Note about Data and Definitions

The Crowdsourcing and Citizen Science Act of 2016 (15 USC 3724) encourages federal agencies to use crowdsourcing and citizen science, where appropriate, to enhance research, education, monitoring, and program operations (Office of Science and Technology Policy (OSTP), 2019).

Data Findings

A report from OSTP that included a review of activities that were directly undertaken by federal agencies (which does not include citizen science funded through grants) in fiscal years 2017 and 2018 revealed more than 700,000 participants across 18 active crowdsourcing and citizen science activities. Most activities were online, allowing access from anywhere in the U.S. This report will serve as a baseline to track projects and citizen engagement in science over time. A useful adjunct would be the compilation of citizen science activities that are funded by federal agencies through grants and contracts.

Analysis

Besides the required tracking of federally led citizen science activities as part of the Crowdsourcing and Citizen Science Act of 2016, there is no central repository of citizen science activities in the U.S., of which there are a large number in a wide variety of areas, including environmental and biological monitoring. One example is the annual Christmas Bird Count, which is sponsored by the non-profit National Audubon Society (National Audubon Society, n.d.). CitSci.org was developed through the Natural Resources Ecology Lab (NREL) at Colorado State University as an initiative to promote citizen involvement in scientific research (CitSci.org, n.d.; Wang et al., 2015). According to their website, as of the end of 2020, nearly 1000 projects have been initiated through CitSci.org. Authors of a scholarly review of citizen science in the social sciences and humanities concluded that social science theories are infrequently used in citizen science (Tauginienė et al., 2020).

Recommendations

3. The U.S. government should consider strategies and potential funding opportunities to support citizen science projects.

4. The U.S. government should study the impacts of citizen science, including on science literacy, public perceptions of science, support for funding of science, and time from discovery to implementation.

5. The U.S. government should fund research to establish best practices for public engagement in science.

The UNESCO Recommendation

> "Member States should treat public funding of research and development as a form of public investment the returns on which are, for the most part, necessarily long-term, and take all appropriate measures to ensure that the justification for, and indeed the indispensability of such investment is held constantly before public opinion." (Recommendation II, 6)

> "Member States should take measures to… encourage the spirit of service both to the advancement of science and to social and ecological responsibilities toward their fellow nationals, humanity in general, future generations, and the earth including all its ecosystems, its sustainable development and its conservation, as an important element in their education and training." (Recommendation III, 13(d))

> "Member States should bear in mind that the scientific researchers' sense of vocation can be powerfully reinforced if they are encouraged to think of their work in terms of service both to their fellow nationals and to their fellow human beings in general. Member States should seek, in their treatment of and attitude towards scientific researchers, to express encouragement for this broad spirit of responsibility." (Recommendation IV, 15)

> [See also Recommendation III, 14(d)(vi), Recommendation IV, 16(a)(iv)]

A Note about Data and Definitions

The distinction between public and private interest

Private-interest research aims to serve the interests of private, typically corporate or business, entities. *Public-interest research* seeks specifically to promote the public good. Within the context of public-interest research, we can distinguish three types—*basic research*, *regulatory or advisory research*, and *mission-driven public-interest research.*

The exact parsing of STEM research into these categories, and the relationships between these types of science, is a matter of controversy. Many think of public interest science as promoting the public good through non-commercial means, as generally not funded by private industry, and sometimes as fully independent from government institutions (though likely advocating with such institutions). However, this common framing is problematic, as funding sources and aims or interests are *not* always linked. Private foundations and philanthropies fund public interest research. At the same time, much public funding goes into curiosity-driven directions or becomes private interest research (through private interest technology transfer and licensing

arrangements). The categories of public- and private-interest research concern the aims or goals of the research.

Data Findings

History and issues of public- and private-interest science

Historically, we can pick out four key concerns from four key moments in the recent development of public interest science: 1) the opposition to nuclear weapons and broader anti-war movement among scientists in the 1950s-1960s (Moore, 1993; Moore, 1996); 2) scientists interested in environmental protection and suspicious of the executive branch science advisory and regulatory system in the 1970s (Hippel & Primack, 1972); 3) scientists, policy scholars, and others concerned about the growing number of abuses in commercialized medical and industrial research in the late 1990s and early 2000s (Krimsky, 2003); and 4) scientists concerned about the status of science vis-a-vis the government in the wake of significant political shifts that occurred in Europe and the U.S. in the mid-2010s. These moments and concerns are, of course, overlapping and connected in various ways.

Throughout this history, a number of organizations have played a significant role in advocating public interest science: Scientists' Institute for Public Information (SIPI), the Union of Concerned Scientists (UCS), Scientists and Engineers for Social and Political Action (SESPA), Science for the People (SftP) (old and new versions), the Center for Science in the Public Interest (CSPI), the Association for Science in the Public Interest (ASPI), and others. The U.S. National Science Foundation (NSF) itself in the past had two programs specifically focused on public interest research, "Interdisciplinary Research Relevant to Problems of Our Society (IRRPOS)" (1970-1971) and "Research Applied to National Needs (RANN)" (1972-1978), and today seeks to integrate public interests into every proposal through the "Broader Impacts" criterion. Another nascent effort concerns the emergence of universities working on public interest technology and civic-minded engineering.

In spite of support from these organizations and ad hoc measures taken to integrate public concerns into the science research and funding infrastructure, universities and public research institutes are not entirely free from institutional factors which are thought to frustrate the aims of public interest science. These include the Bayh-Dole Act of 1980 and the subsequent increase in commercialized research, the increased demands for mainstream publication and grant funding dollars as requirements for tenure and promotion, and decrease of public funding for education and research (Brown, 2002; Krimsky, 2003; McGarity & Wagner, 2008).

Public and private funding of science

Although there are public sources of funding for private-interest science and vice versa, funding sources may be a coarse-grained measure for the proportion of public- and private-interest science. According to NSF's *The State of U.S. Science and Engineering 2020* (Science and

Engineering Indicators, hereafter "Indicators, 2020"), the business sector accounted for over $380 billion or 70% of US research & development funding in 2017, with the remaining funding coming from government, higher education, and nonprofits. The federal government was the second-highest spender, spending over $120 billion or 22% of the US R&D (research and development) funding. Of the $548 billion total spend in US R&D, 17% of that is spent on so-called "basic research," the only category where public funding exceeds private funding from business, with about 42% of basic research funding coming from the federal government, though "the share of basic research funded by the business sector increased from 19% to 29%" (Indicators, 2020).

Analysis

There is no doubt that some public/private partnerships produce both significant benefits in the public interest, as the COVID-19 pandemic illustrates. On the other hand, the prevailing model that relies significantly on private funding and, therefore, private interest in financial benefit, has been demonstrated to undermine equitable access to the benefits of scientific research and development.

The COVID-19 pandemic provides a useful case study for illustrating the impacts of prevailing research and development funding models, and a helpful juxtaposition to the impacts of such models in non-pandemic times. In the U.S., government-funded research provided the vital foundation for successful vaccine research and development that was undertaken in response to the pandemic (Allen, 2020). At the same time, public funds have been used by governments to pay the private sector to rapidly produce the vaccines for deployment. As such, both the intellectual contribution made by publicly funded research and additional public funds have resulted in both public and private benefits.

In the non-pandemic era, however, this model can often favor private interests at the cost of ensuring broad public benefit and access, particularly among poor communities. An often-cited example is that of neglected diseases. In 2017, the Brookings Institution reported that of an annual total of at least $159.9 billion spent on overall health research and development, $5.9 billion was spent on research and development focused on the developing world, and $521 million on neglected diseases that primarily impact populations in very poor nations (West et al., 2017). The U.S. is not immune to this effect. During the Zika crisis, an analysis revealed the high proportion of residents in the five U.S. Gulf Coast States that suffered from at least one neglected tropical disease, and the disproportionate health burden carried by poor African Americans and African American women, in particular (Hotez & Jackson Lee, 2017). Neglected tropical diseases are just one example of an area ripe for potential scientific research and development but which attracts minimal private investment interest as a result of the characteristics of the "market" that is affected—with regard to size, but particularly, wealth.

Recommendations

6. **Federal agencies should consider allocating additional funding to public interest science, including potentially high-yield projects in mission-driven public-interest research.**

7. **Public funding is needed to support research that explores how, in what circumstances, and with what social impact policy changes have driven public funding into private-interest science.**

8. **Public funders of science and recipients should be encouraged to explore humanitarian licensing options to promote access to and use of scientific and technological innovations by historically disadvantaged populations.**

2. Science in National Policy and Decision-Making

Trust in science

The UNESCO Recommendation

The UNESCO Recommendation calls on member countries to ensure that:

> "In order to have a sound science, technology and innovation system integrated to their effort, Member States should establish and substantially strengthen human and institutional capacities, including by…strengthening scientific culture, public trust and support for sciences throughout society, in particular through a vigorous and informed democratic debate on the production and use of scientific knowledge, and a dialogue between the scientific community and society" (Recommendation II, 5(c)).

A Note about Data and Definitions

There is a widespread impression amongst scientists, science advocates, and others that public trust in or the cultural authority of science in the U.S. has eroded significantly in recent years. At least some Americans do not believe that climate change is real, think that vaccines do more harm than good, and are skeptical of genetically-modified crops. And for quite some time, a rather high percentage of Americans have rejected the basic claims of evolutionary biology. What's more, these claims are seen as part of a larger, worrying trend in which the entire scientific enterprise has lost its epistemic and cultural authority (Cross, 2021). The available data paint a somewhat different and more optimistic picture of the public attitudes towards and trust in science and scientists. The data in this section are drawn primarily from the NSF *Science & Engineering Indicators* series of reports and from Pew Research surveys.

Data Findings

The NSF *Science & Engineering Indicators* report *Science and Technology: Public Attitudes, Knowledge, and Interest* contains a comprehensive account of Americans' perceptions about science. According to 2018 survey results, 92% of Americans agree that science and technology create more opportunities for the next generation; 74% believe that the benefits of science outweigh the harms; 84% agree that the government should fund basic scientific research, and 87% thought the level of funding should remain the same or be increased (43% said funding was too low, 44% about right). In terms of indicators of trust in scientists, 44% of Americans had "great deal" of confidence in the leaders of the scientific community (47% had "some" confidence), making scientists the second-most trusted institutional leaders after the military (and ahead of medicine, the Supreme Court, education, and organized religion). A significant percentage of surveyed Americans agreed with statements such as:

- "Scientists are helping to solve challenging problems" (93%).
- "Scientific researchers are dedicated people who work for the good of humanity" (90%).
- "Most scientists want to work on things that will make life better for the average person" (89%).

In addition to demonstrating relatively high levels of public trust in science, it is noteworthy that these results have by and large remained stable since the 1970s, ranging a few percentage points in either direction. Confidence in scientific leaders has remained stable when confidence in the leaders of other institutions has been in flux, with the military increasing in status since the 1970s and 1980s, while confidence has declined in the leaders of medicine, major companies, and the press. And when it comes to the statements that indicate public trust in scientists' aims, not only has the very high-level agreement remained stable for decades, the number of those who "strongly agree" with those statements has increased. Far from indicating any growing dissatisfaction, distrust, or disrespect for science, the data on public perceptions seems to indicate a stable, high level of trust in scientists and scientific results.

Climate change is an area where at least some Americans seem to be distrustful of science and the authority of scientific assessments. Yet the NSF *Indicators* data show that there has been significant increase in perceptions of the dangers associated with climate change, with 58% of respondents in 2018 indicating concern for those dangers, up from only 35% in 1994. Other polls show similar trends with respect to climate concerns over time. According to a 2019 Pew Research poll, a majority of Americans believe that human activity contributes to global climate change—49% say "a great deal," and another 30% say "some" (Funk & Hefferon, 2019c). On this and most scientific issues of public concern, most Americans agree with the scientific consensus, though there is a sizable minority that often dissents.

There are a few public concerns about science as well, however. Just fewer than half of Americans agree that "science makes our way of life change too fast," a number that has been fairly stable over the last decade, but which has increased as compared to the mid-1980s to early-2000s (Indicators, 2020). It is, therefore, not surprising that Pew Research surveys show that Americans have mixed views on the impact of emerging or anticipated science and technology such as genetic engineering, human cognitive enhancement, and automation, despite the fact that most Americans (73%) say that science has a "mostly positive" effect on society (Funk, 2020).

A majority of Americans disagree in particular with the views of the scientific majority on the safety of genetically-modified (GM) foods and foods grown with conventional chemical pesticides. According to the 2015 comparison by Pew of their own survey of citizens with an American Association for the Advancement of Science (AAAS) membership survey, a large majority (88%) of AAAS scientists agree that it is safe to eat GM foods, while only 37% of the public agrees (a 51-point gap) (Pew, 2015a). A slimmer minority of AAAS scientists (68%) believe food grown with pesticides is safe, but even fewer sampled U.S. adults (28%) agree (a 40-point gap). By contrast, while smaller but sizable gaps exist with questions concerning

climate, vaccines, or human evolution, the majority of U.S. adults agree with the majority of scientists. The only question in this 2015 comparison that had comparable levels of disagreement concerned the use of animals in research—only 47% of the public is in favor of such use, whereas 89% of scientists are in favor of it (a 42-point gap).

Despite the overall positive picture of public trust in science, there are some important partisan differences. Surveys show that more liberals than conservatives have a favorable view of scientific experts in policy debates, believe in the effectiveness of "the scientific method" and the objectivity of scientists (Funk et al., 2019a). Increased scientific literacy is likely to increase liberal voters' belief in anthropogenic climate change, but it is likely to decrease conservatives' belief in the same (Kahan, 2015). On the other hand, some moderately controversial questions (like the safety of vaccines) have no partisan associations (Funk, 2020). Americans tend to trust practitioners (medical doctors, nutritionists) more than scientific researchers in the associated area, although they have a generally positive view of both (Funk et al., 2019b). The difference here is likely a result of both the greater familiarity of the public with the work of practitioners, as well as the fact that the practitioners but not the researchers are generally understood as having the interests or wellbeing of those in their care as a central aim.

Analysis

Positive perceptions, with understandable exceptions

By and large, the data present an optimistic picture of public trust in science. Most Americans trust scientists and the scientific consensus on most issues. In a few prominent instances, however, this is not the case. Areas of disagreement can concern questions of basic science (have humans evolved from other species, does human activity contribute to climate change, do vaccines cause autism?), risk assessments (food safety, emerging technology) and ethical questions (whether it should be permissible to conduct animal research). The latter sort of disagreements can sometimes be understood as legitimate, as different assessments of risk based on different value judgments. Moreover, Americans have to navigate a variety of different sources of information about many of these issues, which may or may not be truly grounded in scientific evidence. For example, Americans are constantly inundated with messages about what they eat and how it is healthy or unhealthy. What is more, this is an area where scientific recommendations concerning nutrition have been mercurial, inconsistent, and often overreaching (Aschwanden, 2016). What can complicate matters is that GM foods are closely associated with large-scale industrial agriculture, and the latter has been subject to critiques in terms of health, safety, and environmental impact. In this context, the normally high level of trust of the American public for science has eroded.

Facilitating trustworthiness of science

Public mistrust of science is a more pressing problem than misinformation or scientific illiteracy; facilitating trustworthiness of science is the most promising approach to improving science-

society relations and the role of science in national policy (Goldenberg, 2021). Scholarly analyses of trust show that it is a complex phenomenon of epistemic dependence that makes the trustor vulnerable to the trustee. The proper functioning of science and in particular science taking its proper role in society requires relationships of trust between the public and scientific experts. Fostering trust requires the use of certain effective communication practices that involve engagement in both directions (Grasswick, 2010; Goldenberg, 2016).

Trustworthiness requires not only a recognition of the *competence* of scientists but also their *integrity* (Scheman, 2001; see §2.h Social Responsibility and §3.d Scientific Integrity). This second criterion requires that scientists not only uphold standards of good research, but also that they are responsible or conscientious of those who rely on their results (Baier, 1986; Jones, 1996; Almassi, 2012). In order to facilitate public trust in science, scientists must cultivate relationships with the public that demonstrate that they are not only competent but epistemically and morally responsible in regards to the interests of the public.

Studies have shown that certain public controversies over science have strong partisan associations, while others do not. Better communication of scientific information is insufficient in general for creating public trust in science. In cases where there is partisan polarization about a scientific issue, an approach that focuses on better communication of the science can actually be counterproductive (Kahan, 2015). However, in other cases, the public controversy about the science has no partisan associations, for example, vaccine hesitancy and vaccine refusal. In such cases, there is more hope that public trust in the science can be fostered and it is important not politicize such issues. Relating all cases of public mistrust of science in a narrative of a political "war on science" is a particularly pernicious communication strategy.

Another component of facilitating trust between the scientific community and the public is that individual scientists and their organizations need to avoid exaggerating or misleading the public about scientific findings. For example, if a scientist were to state that a vaccine or other medical treatment is "risk-free," that would be dishonest. Granted, a given treatment may have relatively minor side effects or negatively affect a relatively small portion of the population, but arguably there is no such thing as a treatment that has zero risk. In sum, scientific findings should be described accurately and transparently.

Recommendations

9. **Federal agencies should consider funding research on what facilitates and erodes trust in science.**

10. **Publicly-employed/-funded scientists should be encouraged and recognized for efforts aimed at cultivating relationships with the public that foster a sense of trustworthiness.**

11. **The science communication ecosystem should work to decouple partisan identities from public science controversies by emphasizing that the issues at stake are not strictly**

partisan.

12. The federal government should consider funding programs that research, monitor, and respond to science mis/disinformation over online platforms.

Independent science

The UNESCO Recommendation

The UNESCO Recommendation calls on member countries to ensure that:

> "Member States should create the environment to ensure that scientific researchers, who give policy advice to policy-makers and other public officials, can do so in an accountable manner in which conflicts of interest are disclosed." (Recommendation II, 9)

> "Each Member State should institute procedures adapted to its needs for ensuring that, in the performance of research and development, scientific researchers respect public accountability while at the same time enjoying the degree of autonomy appropriate to their task and to the advancement of science and technology." (Recommendation II, 10)

A Note about Data and Definitions

There is a limited number of data sources that assess conflicts of interest and losses of science independence in a government context. In the US, much work in this area comes from legal scholars, nongovernmental organizations, and government reports, including, for example, reports of the Government Accountability Office (GAO) and the nonprofit Union of Concerned Scientists (Wagner et al., 2018; MacKinney et al., 2020; GAO, 2020). In the U.S., relevant policies at the federal level fall under the umbrella of federal scientific integrity policies, peer-review policies, and other government policies and procedures that govern the process by which science is funded, conducted, reviewed, and used to inform policy decisions in a federal government context. Such issues concern both researchers working within the government and those informing policy decisions from outside of it, such as researchers serving on federal science advisory committees, university researchers collaborating with government actors, and researchers receiving government funding.

Data Findings

The U.S. has a long tradition of science-based and science-informed decision making across the federal government, from food and drug safety to environmental pollution to worker safety standards (Goldman et al., 2017). However, politicization of science in the federal government context has increased in recent years (Goldman et al., 2020). Such instances have been closely tracked for the past several decades (Berman & Carter, 2018). Examples of such losses of

independence have included the suppression, manipulation or halting of scientific documents, the appointment of conflicted decisionmakers, communication restrictions on scientists, undue political influence over decisions that should be science-based such as grant-funding decisions, and other disruptions to the processes by which science should be conducted and communicated in the federal context.

Politicization of federal science has occurred under presidents of both major political parties, with ebbs and flows over multiple past administrations (Berman & Carter, 2018; Carter et al., 2021). Problems have included conflicts of interest in decisionmakers, for example, when agency heads have come from industries that they were subsequently responsible for regulating, and when federal science advisory committees have failed to meet as often as their charters specified, some disbanded, and others populated with less qualified or conflicted individuals (Union of Concerned Scientists, 2018).

Analysis

The independence of science and scientists in national policy and decision making is threatened by the politicization of scientific work and processes. Several vulnerabilities, loopholes, and instances of lack of transparency create conditions under which politicization of science happens. Policies guarding against such interference in science are inconsistent across federal agencies and agencies have varying levels of capacity to devote to educating employees, investigating allegations, and enforcing policies. A unique challenge in recent years is the circumstance of presidential or federal agency leaders themselves politicizing science or directing it. Given existing power structures and policy and legal frameworks, there has been little opportunity for recourse and accountability under such circumstances.

Consistent and strong protections for federal science and scientists are needed to better ensure the independence of science in national policy settings. Such protections should include ensuring government scientists are able to freely speak to the public and media, better insulating science advice from political actors, and developing clear and streamlined processes for investigation of allegations of politicization and robust enforcement mechanisms (Union of Concerned Scientists, 2020a; Union of Concerned Scientists, 2020b; Kurtz & Goldman, 2020). Many solutions exist to strengthen disclosure and management of conflicts of interest in science advice and evidence-based policy decisions (Kelly et al., 2021). Additionally, the U.S. can glean solutions from the experience of other nations that have worked to address similar issues of politicization of science (Carroll et al., 2017).

The Biden administration has taken several steps to begin addressing these challenges (Carter et al., 2021). A presidential memo on scientific integrity and evidence-based policymaking was issued that would review federal policies that protect science and scientists from political interference, form a scientific integrity taskforce, and review advisory committees for any changes needed (The White House, 2021b). President Biden has also indicated that his administration will review recent federal actions for any policy decisions made in the previous

administration that are inconsistent with their intention to make evidence-based policy decisions (The White House, 2021b). It is critical that the Biden administration follow through on these efforts and fully implement changes that will strengthen the independence of the U.S. government's use of science. Additionally, the U.S. Congress can play a key role. Several bills have been proposed in Congress that would address these issues. The Scientific Integrity Act, for example, would strengthen protections for science and scientists by codifying and standardizing across the government several key provisions of federal scientific integrity policies (Tonko, 2021).

Recommendations

13. **The U.S. government should better track, analyze, and make public all available data on conflicts of interest and scientific independence in the U.S. federal government.**

14. **The U.S. government should take steps to strengthen federal protections for science and scientists working in policy contexts. Such efforts should include strengthening scientific integrity policies across all federal science agencies, improving consistency in policy and practice across the government, and appointing science agency and White House decisionmakers who can provide strong leadership on independent science.**

15. **To address conflicts of interest in science advice settings, the U.S. government should strengthen its oversight and guidance on conflict of interest in order to create more transparency and accountability around the formation, appointment, activities, and disbanding of science advisory committees.**

3. Science as a Common Good

Open access and open data

The UNESCO Recommendation

> "Member States should take measures to… ensure equitable and open access to scientific literature, data and contents including by removing barriers to publishing, sharing and archiving of scientific outputs." (Recommendation III, 13(e))

> "In order to promote science as a public good, Member States should encourage and facilitate access to knowledge, including open access." (Recommendation V, 36)

> [See also Recommendation IV, 16(a)(v))

A Note about Data and Definitions

"Open access" and "open science" are two distinct but related terms. Open access involves the free, immediate, online availability of research articles. There are currently various routes to open access, including with differences in the rights to reuse the published articles. Open data concerns research data that is freely available, allowing for further analysis and re-processing. Such data may include datasets, statistics, transcripts, survey results, and metadata. Open access and open data are each elements of, but distinct from, open science, which is as much, if not more, about sharing knowledge to facilitate open research collaborations as it is about access to the final outputs.

Data Findings

Since 2008, the US National Institutes of Health (NIH) have mandated open access for research publications resulting from NIH funding (NIH, 2014). Since 2013, NSF has also mandated open access to publications resulting from NSF funding (NSF, n.d). NIH and NSF encourage funded researchers to share data openly when possible. Yet there are concerns that can render data sharing difficult or impossible such as if making the data public might lead to identifying individual research participants. In October 2020, NIH issued an updated Policy for Data Management and Sharing, which goes into effect on January 25, 2023 (NIH, 2020).

In addition to access to publications resulting from federal funding, there has been a move toward accessibility of government data, specifically. On May 9, 2013, President Obama signed an executive order that made open and machine-readable data the new default for government information. Project Open Data (https://resources.data.gov/), a collection of code, tools and case studies, was developed to help federal agencies make their data publicly available. The U.S. government's open data are housed on the website data.gov.

More recently, the Biden administration issued a presidential memo that includes efforts to "expand open and secure access to federal data" and directs federal agencies to develop open data plans that encourage federal data to be more open, accessible, machine-readable, and "disaggregated by race, gender, ethnicity, age, income, and other demographic factors that support researchers in understanding the effects of policies and programs on equity and justice" (The White House, 2021b). These efforts are aimed at expanding federal open data initiatives from the Obama administration.

Analysis

A recent review found that 45% of scholarly literature was published open access in 2015 and that articles published open access receive 18% more citations on average; data were published by journal, not location of author(s) (Piwowar et al., 2018). Researchers of a study of open access publishing at American research universities from 2014-2018 found 53.7% of articles had restricted access, and found that scholars were more likely to publish open access if they were male gender, employed at a prestigious institution, associated with a STEM discipline, had greater federal research funding, and were more advanced in their career (Olejniczak & Wilson, 2020).

Open access to journal articles can certainly be beneficial to readers but it can shift the publication costs from subscribers to the authors, their organizations, and non-profit publishers. This can place those authors without the resources to pay such costs at a disadvantage in the effort to find a publication venue thereby perpetuating or further exacerbating persistent inequities for authors based on race, gender, geography, discipline, and/or institution.

Recommendations

16. **The U.S. government should develop clear guidelines for making federally funded research open access and open data publicly available. The U.S. government should host data on their repositories through a link from research articles.**

17. **Federal sponsors should address inequities associated with costs to researchers of open access publication.**

18. **Research funded publicly should support reasonable costs associated with open access publishing.**

19. **The federal government should fully implement its plans to expand open data initiatives and infrastructure, with a focus on ensuring data is shared in accessible and useful formats and an emphasis on disaggregated demographic data that will enable researchers to better study and identify inequities in government services and public benefits of science.**

4. Inclusive and non-discriminatory work and access to education

Diversity, Equity and Inclusion (DEI) in the STEM workforce

The UNESCO Recommendation

The UNESCO Recommendation calls on member countries to:

> "[I]n order to remediate past inequalities and patterns of exclusion, actively encourage women and persons of other under-represented groups to consider careers in sciences, and endeavour to eliminate biases against women and persons of other under-represented groups in work environments and appraisal." (Recommendation III, 13(c))

Similarly, the Recommendation urges member states to:

> "(b) [E]nsure that scientific researchers enjoy equitable conditions of work, recruitment and promotion, appraisal, training and pay without discrimination on the basis of race, colour, descent, sex, gender, sexual orientation, age, native language, religion, political or other opinion, national origin, ethnic origin, social origin, economic or social condition of birth, or disability;
> "(c) support individuals from underrepresented groups entering and developing careers in research and development." (Recommendation V, 24(b)(c))

In paragraphs 33 and 34 (not quoted in full here), the Recommendation calls for member states to provide "adequate and equitable social security arrangements" for scientific researchers and performance evaluation that does not disadvantage those who take family or parental leave (Recommendation V, 33, 34(d)).

A Note about Data and Definitions

Statistics about who participates in the U.S. STEM workforce are based on data collected by U.S. government agencies, including the U.S. Census Bureau, the Bureau of Labor Statistics, and the National Science Foundation. These include the U.S. Census, which is mandated by the U.S. Constitution and held every ten years, and the American Community Survey (ACS), which is carried out on an ongoing basis. The Census, intended to count every U.S. resident, asks every household basic questions such as how many people live in their home, race, age, and sex. The ACS, sent to 3.5 million people per year, asks more detailed questions such as place of birth, citizenship, disability, educational attainment, and occupation.

The data derived from these surveys form the basis of two leading reports—both mandated by the U.S. Congress and issued biennially—that monitor trends in the STEM workforce: The National Science Board's *Science and Engineering Indicators* (hereafter "Indicators, 2019") and

the National Science Foundation (NSF)'s *Women, Minorities, and Persons with Disabilities in Science and Engineering* (hereafter "WMPD, 2019"). The National Center for Science and Engineering Statistics (NCSES) prepares the reports and complements the above data sources with its own additional surveys. One other survey providing detailed publicly accessible information about STEM faculty is the National Science Foundation Higher Education Research and Development Survey which collects, among other data, headcounts of research and development personnel at U.S. colleges and universities.

One challenge in assessing the data is that there is no agreed-upon definition of "STEM workforce." Surveys provide varying definitions of "STEM fields," or differ on whether to include people with STEM-related degrees who do not currently work in STEM fields. For example, the *Indicators* describe how the size of the U.S. STEM workforce can be defined as anywhere from the approximately 7 million people who work in STEM occupations to the nearly 25 million who hold at least a bachelor's degree in a STEM-related field (Indicators, 2019). For its part, based on ACS data, a 2018 Pew report calculates "STEM employment" in the U.S. at 17.3 million people (Funk & Parker, 2018).

Definitions of which occupations are considered "STEM fields" also vary. The *Indicators* report (which uses the term "S&E," for science and engineering, rather than STEM) defines them as including "computer and mathematical sciences, life sciences, physical sciences, social sciences, and engineering. S&E occupations fall into these same five broad occupational categories and include postsecondary teachers of these same broad fields of study" (Indicators, 2019). Health-related fields are often not included in the *Indicators*' definition. Due to the lack of a single standard and in the interest of producing a report of broad relevance, we choose to follow a broad approach in defining who is part of the U.S. STEM workforce and what fields are included.

Which Demographic Groups?

Groups that are considered "underrepresented" in STEM hold a smaller share of STEM degrees and employment in the STEM workforce than they should if they were represented according to their share of the U.S. population (WMPD, 2019). In addition to groups who are specifically designated under US law as underrepresented in STEM (African Americans, Hispanic/Latinx populations[3], and Indigenous people[4]) the NSF WMPD report also includes two other groups

---

[3] Hispanic/Latinx populations can be of any race. There continues to be debate, including within Hispanic/Latinx communities, about using the term "Latinx" (which is inclusive of individuals who identify as neither male nor female) in place of the more traditional "Latino" or "Latinos/Latinas." Whenever possible, we employ both "Hispanic" and "Latinx" here in the interest of being as inclusive as possible and to be consistent with usage in other AAAS publications.

[4] Terms for Indigenous populations in the U.S. vary. Many Native people prefer to be identified by the name of their Nation (e.g. Navajo, Wampanoag). The Census uses "American Indian," which some communities prefer; another alternative is "Native American" (which some communities prefer to avoid). Depending on the survey, Indigenous populations may be sub-grouped into one or more specific categories, e.g. "Native Hawaiian/Pacific

who historically have faced discrimination: women and persons with disabilities. One prominent minority group, Asian Americans, is not included because they are statistically represented above their share of the population among people who obtain STEM degrees and are employed in the STEM field (WMPD, 2019; Indicators, 2019). That said, this does *not* mean that Asian Americans do not face similar challenges (such as racist violence and discrimination) as other marginalized groups. Furthermore, data on Asian Americans lumps together many different communities (such as Chinese Americans, Filipinos, and Hmong). Some of these groups may be appropriately represented, but others may not. We also include one population for whom more data is needed: the LGBTQ+ (lesbian, gay, bisexual, transgender, queer) community.

Women

Data Findings

Women are a majority of the U.S. population but are underrepresented in numerous STEM fields. In 2016, women and men were roughly equal in receiving STEM bachelor's degrees. Women received 44% of master's degrees and 41% of doctorates (WMPD, 2019). While the number of women who hold STEM degrees or work in STEM fields has doubled since 1995, in 2017 women still made up less than 30% of workers in STEM occupations, even though they are 47% of the labor force (Indicators, 2019).

According to 2019 figures calculated by Dr. Lindsey Malcom-Piqueux based on NSF data and a 2014 analysis by former *Scientific American* executive editor Fred Guterl, white men comprise 32.2% of the U.S. resident working-age population (between ages 18-64) but make up 47.5% of the science and engineering workforce (Malcom-Piqueux & Malcom, 2019; Guterl, 2014). White women are 32.3% of the U.S. resident population, but just 17.5% of the STEM workforce. Women of color are particularly underrepresented. Black women are 6.5% of the resident population but 2.5% of the STEM workforce. Latinas are 7.7% of the resident population and just 2.3% of the STEM workforce.

Indigenous women (encompassing those whom the data categorizes as American Indians, Alaska Natives, and Native Hawaiians) are approximately 0.5% of the resident population. Reliable estimates of their percentage of the STEM workforce are difficult to find. One reason for that is cell counts in these studies are often so low for Indigenous scholars that their reporting is often subsumed into the "Other" category. Sometimes this is done because the reporting of the low numbers would constitute identifiable data. While this is considered good practice from a data ethics standpoint, it simultaneously serves to re-marginalize these individuals. Such erasures have reifying effects upon the community which serve to limit STEM aspirations among future indigenous scholars—a vicious cycle. The NSF's new "Making the

---

Islander" and "American Indian/Alaska Native." As this report is aimed at a global audience, we choose to use "Indigenous" here, except where "American Indian" is employed by a specific data source.

Invisible Visible" campaign is specifically targeted at this issue with a focus on recognizing the "under-underrepresented groups" in STEM.

The presence of women varies greatly by scientific discipline. Women are more concentrated in life sciences (48%) and social sciences (59%). Representation of women is lowest in the physical sciences, computing and mathematical sciences (each around 30%), and engineering (16%, including just 7% of mechanical engineers). Still, this data largely represents an increase in most fields since the 1990s, when the percentage of women in engineering, for example, was just 9%. An exception is the growing fields of computing and mathematical sciences, where the percentage of women has decreased from 31% in 1993 to 27% in 2017, even though three times as many women work in the field as they did a generation ago (Indicators, 2019).

Median salaries for women employed full time are generally lower than men's across STEM occupations. According to NSF data, the overall median salary for women across all STEM occupations is $66,000, compared to $90,000 for men. Certain fields such as computer and information sciences ($84,000 median salary for women, $100,000 for men) and physical sciences ($62,000 for women, $80,000 for men) have particularly stark disparities. In fields where women form a greater portion of the workforce, such as social sciences and life sciences, the gap is closer, although in both cases men's median salaries are $4,000-$5,000 more (WMPD, 2019).

Another disparity is in the type of work performed by women. In some fields like health, women are an overwhelming majority of workers (71% per the most recent *Science and Engineering Indicators*). Yet women are only 44% of practitioners responsible for diagnosing and treating patients. Most are "employed primarily as nurse practitioners, pharmacists, registered nurses, dietitians, therapists, physician assistants, and health technologists and technicians" (Indicators, 2019).

Though women remain underrepresented in academia, this is one area where gaps with men may be narrowing. The percentage of women with STEM doctorates with jobs in academia rose from 25% in 1997 to 38% in 2017. In 2017, 32% of full-time senior faculty in STEM (i.e., associate or full professors) were women, up from 17% two decades prior (Indicators, 2019).

Analysis

There are many explanations for these disparities (see Access to Quality STEM Education, pp. 32-43, for more information). Evidence suggests that isolating and demanding workplace cultures, harassment, and bias (implicit and explicit) are all substantial factors in why women leave the STEM workforce (Corbett & Hill, 2015). Environments can be particularly hostile for women of color, who are more likely to face sexual harassment and on-the-job stress from cultures that often demand they work harder to prove their "legitimacy" (Corbett & Hill, 2015; National Academies, 2018b) and who are often taxed with additional service burdens.

Moreover, women in STEM jobs are more likely than women in non-STEM jobs to say they have experienced discrimination at work (Funk & Parker, 2018).

Another factor is family responsibilities, such as caring for a child or elderly relative. In looking at unemployment or part-time employment among scientists and engineers, "Almost three times as many women as men report that they are not employed, not looking for work, and not retired" (WMPD, 2019). When asked for their reasons for not working, 27% of women cited family responsibilities; just 6% of men did. Among part-time employed scientists and engineers who would ideally work full time, 45.7% of women, and 19.5% of men, cited family responsibilities as a reason (WMPD, 2019). The increased burden of dependent care being borne by women has been exacerbated by 2020-21 COVID-19 pandemic.

While salary data reflects clear disparities, some caution is warranted. As the *Indicators* report notes, "differences in average age, work experience, academic training, sector and occupation of employment [e.g. government vs. private sector], and other characteristics can make direct comparison of salary statistics misleading" (Indicators, 2019). Nevertheless, after controlling for these effects, disparities remain. Among those whose highest degree is in a STEM field, women with a bachelor's or doctoral degree earn 9% less than men. For master's degree recipients, women earn 10% less (Indicators, 2019).

Overall, in most fields of the STEM workforce, with some exceptions like computer science, representation of women appears to be growing (Myers, 2018). However, numerous barriers exist to women's advancement in STEM fields, particularly for women of color, including bias, workplace culture, and caregiving responsibilities. There is early evidence that the COVID-19 pandemic may set back recent gains for these groups by exacerbating the factors mentioned here (Woolston, 2020; Cardel, 2020). For example, women of color serve as caregivers (both paid and unpaid) at disproportionate rates, and may face greater risk of illness and death from COVID-19 due to structural racism and inequality (500 Women Scientists, 2020; Erickson, 2020). People of color, who are disproportionately represented among "essential workers," are more likely to become ill or die from COVID-19 or be affected by its economic impacts, such as job loss (Mitchell, 2020).

Recent data indicates that the pandemic has disproportionately affected researchers who are mothers. Studies have shown a decrease in the percentage of women authors on preprints, manuscripts, and published papers, and that mothers' research hours have declined 33% more than fathers' have (Langin, 2021). With many children staying at home during the pandemic, researchers who are mothers are more likely to spend more of their time on child care and housework than fathers do (Langin, 2021).

There are numerous potential actions that could be taken to address these inequities. A 2020 article in *Scientific American* mentions several possible approaches, including encouraging employers to better support caregiving and government action to promote policies such as family leave, which is mentioned by the UNESCO Recommendation (Torres et al., 2020). While

written before the pandemic, the American Association of University Women's 2015 report *Solving the Equation* provides numerous suggested actions the U.S. government can take, including funding education and workforce training and authorizing additional data collection (Corbett & Hill, 2015). Such an approach could be extended to underrepresented minorities as well, with a particular eye on the circumstances of women of color and others at the intersections of multiple identities. An Interagency Policy Group during the Obama Administration issued recommendations in 2016 for federal government actions to mitigate bias in the STEM workforce that could also be revisited (Handelsman & Ward, 2016).

Underrepresented Groups: African Americans, Hispanics, & Indigenous People

Data Findings

African Americans, Hispanic/Latinx populations, and Indigenous people are underrepresented in the STEM workforce. Black men are 5.9% of the resident population ages 18-64, but 3.1% of the STEM workforce; Latino men are 8.1% of the resident population but 5.2% of the workforce (Malcom-Piqueux & Malcom, 2019; Guterl, 2014). Indigenous men are 0.5% of the resident population. As noted above, reliable estimates of their percentage of the STEM workforce are not readily available.

Despite representing something close to 30% of the population and labor force, members of underrepresented minority groups hold approximately 9% of academic doctoral positions in STEM. Factors such as lack of access to rigorous math and science courses or qualified teachers in primary and secondary schools, as well as socioeconomic status (which will be explored in the next section), help explain why these disparities manifest in the STEM workforce (WMPD, 2019).

A study assessing the earnings of full-time STEM workers over age 25 found the median salary was $71,897 for whites, $58,000 for Blacks, and $60,758 for Hispanics. Among women, median salaries were $60,828 for whites, $52,718 for Blacks, and $52,000 for Hispanics. While these numbers are all lower than the median salaries for men, white women have slightly higher median salaries than Blacks and Hispanics overall (Funk & Parker, 2018).

Analysis

One reason behind these disparities is workplace discrimination. 62% of Blacks and 42% of Hispanics employed in STEM report experiencing at least one kind of discrimination due to their race or ethnicity (Funk & Parker, 2018). While still unacceptable, 50% of Blacks and 42% of Hispanics in non-STEM fields report such discrimination (Funk & Parker, 2018). This finding reinforces the importance of devoting special attention to racism, especially anti-Black racism, in STEM. An inability to find mentors who share similar social identities is another important factor, as research suggests the importance of mentorship in ensuring underrepresented minorities stay in STEM (MacPhee et al., 2013).

As the data shows, underrepresented minority groups earn lower median salaries across STEM occupations (WMPD, 2019; Funk & Parker, 2018). However, as mentioned above, salary data can be unreliable for some occupations without controlling for other factors such as occupation, employment sector, and experience (Indicators, 2019). Further analysis of these disparities and recommendations for addressing them will be found in the next section.

People with Disabilities

Data Findings

Approximately 10% of employed scientists and engineers self-report having one or more disabilities, fairly close to their estimated representation of 11% of the population cited by the WMPD report. Data also suggests that disabled people in the STEM workforce earn slightly lower median salaries than people without disabilities, except in engineering (WMPD, 2019).

Analysis

Data on disability should be treated with caution because definitions of disability have changed over time. Increasingly, more Americans are identifying as disabled. Nearly one out of every five college students in 2016 cited having some kind of disability. By the Centers for Disease Control and Prevention's definition, 1 out of every 4 American adults has a disability (CDC, n.d.). For this reason, it is difficult to say how underrepresented people with disabilities are in the STEM workforce, although evidence suggests they are underrepresented at least to some degree. An additional data issue which obfuscates the unique challenges that various subgroups of persons with disabilities have is that existing data tend to aggregate learning disabilities with all other physical disabilities. Further data collection is needed in order to come to reliable conclusions.

LGBTQ+ Populations

Data Findings

Data on LGBTQ+ individuals in STEM is limited because NCSES surveys of the STEM workforce currently do not ask about sexual or gender identity. Research suggests that the LGBTQ+ individuals are underrepresented in STEM by approximately 20%, at least in federal agencies related to STEM (Freeman, 2019; Cech & Pham, 2017), but more data is needed to track employment of LGBTQ+ people across STEM fields.

Analysis

More data on LGBTQ+ employment is needed to be able to reach firm conclusions. However, workplace culture and bias against LGBTQ+ individuals may help explain why this population appears to be underrepresented. A recent study suggests LGBTQ+ people are more likely to

report "systematically more negative workplace experiences than their non-LGBT colleagues" (Cech & Pham, 2017). This is even more so the case for people who identify as transgender (U.S. Commission on Civil Rights, 2017; National Center for Transgender Equality, 2021).

One way to address the data gaps regarding people with disabilities and LGBTQ+ individuals in the STEM workforce would be to add questions about identification as disabled and/or LGBTQ+ to major reports such as *Science and Engineering Indicators* and NSF surveys of the workforce, such as the Survey of Earned Doctorates, Survey of Doctoral Recipients, and National Survey of College Graduates. At the same time, surveys should respect the privacy of individuals who live in states where categories such as sexual orientation and gender are not protected under law (Langin, 2018).

A Culture of Respect and the Prevention of Harassment

Intertwined with the aforementioned issues is the overarching need to foster a culture of respect in science, which includes developing strategies to prevent harassment or other behaviors that might contribute to a toxic work environment for the groups mentioned above, especially people, such as women of color, who have intersecting marginalized identities. This will require the will of the scientific community to critically examine the scientific enterprise, often thought of as a meritocracy, to examine the multiple ways in which power, privilege, and bias are imbued within decision-making and the many systems comprising the STEM enterprise (Tilghman et al., 2021).

The National Academies among other entities has been seeking to develop strategies to address the issue. One important action would be to implement the recommendations for addressing sexual harassment and promoting cultural change in the 2018 National Academies report S*exual Harassment of Women: Climate, Culture, and Consequences in Academic Sciences, Engineering, and Medicine* (National Academies, 2018b).

The situation of trainees in the STEM workforce deserves special attention. Numerous recent studies have demonstrated alarmingly high rates of anxiety and depression among graduate students. A survey of 2,279 students, 40% of them from the fields of biological sciences, physical sciences, or engineering, reported rates of moderate to severe anxiety and depression six times higher than among the general population (Pain, 2018). A 2015 study of students at the University of California, Berkeley found that nearly half of PhD students in science and engineering reported being depressed (Bernstein, 2015). The 2018 study found significant variation by sex: women were more likely than men to report experiencing anxiety or depression (Pain, 2018). While only 42 transgender or gender-nonconforming people responded to the survey, more than half reported feeling anxious or depressed. Research has also shown that students of color are more likely to feel overwhelmed than white students, but are less likely to seek help (Steve Fund, 2020; Langin, 2020).

Institutional and cultural factors seem to contribute to these results. They include lack of work-life balance and unsupportive relationships with principal investigators (Pain, 2018). Among students of color, research points to the mental health effects of racism and microaggressions (Zamudio-Suarez, 2021; Steve Fund, 2020). Evidence suggests that the COVID-19 pandemic has also led to spikes in mental health issues among graduate students (Langin, 2020). As the pandemic deepens what some researchers have called a "mental health crisis," these findings reiterate the importance of fostering a culture of support and respect in science on campus and beyond.

Recommendations

20. For the U.S. government (including executive leadership and federal science agencies) and funders: make addressing inclusion, equity and discrimination in the STEM workforce a key national priority.

21. U.S. government data on the workforce should include more and better information about people from indigenous, LGBTQ+, and disabled identities.

Access to quality STEM education

The UNESCO Recommendation

In paragraph 13, the UNESCO Recommendation calls on member countries to:

(a) "Ensure that without discrimination on the basis of race, colour, descent, sex, gender, sexual orientation, age, native language, religion, political or other opinion, national origin, ethnic origin, social origin, economic or social condition of birth, or disability, all citizens enjoy equal opportunities for the initial education and training needed to qualify for research and development careers, as well as ensuring that all citizens who succeed in so qualifying enjoy equal access to available employment in scientific research;
(b) abolish inequalities of opportunities;
(c) in order to remediate past inequalities and patterns of exclusion, actively encourage women and persons of other under-represented groups to consider careers in sciences…" (Recommendation III, 13(a)-(c))

A Note about Data and Definitions

Access to quality STEM education can be assessed through several metrics, including discrepancies between demographic groups on national assessments; who receives degrees in STEM fields; the availability of qualified teachers; and the availability of science and math courses, especially access to rigorous coursework such as the Advanced Placement (AP) and International Baccalaureate (IB) programs.

The major data sources on access to quality STEM education are reports compiled by the U.S. government, specifically the U.S. Department of Education Institute of Education Sciences National Center for Education Statistics (NCES) and the National Science Foundation (NSF). The list of relevant Department of Education surveys is too exhaustive to be included here (for a recent list, see National Research Council, 2013), but a leading example is the NCES National Assessment of Educational Progress (NAEP), an assessment in various subjects administered to representative samples of fourth, eighth, and twelfth grade school students across the country. In science, the NAEP was conducted most recently in 2009, 2011, and 2015; in mathematics, 2015, 2017, and 2019; and in technology and engineering literacy (TEL), 2014 and 2018. NAEP data help measure student performance over time and gaps between demographic groups.

The Department of Education's Office for Civil Rights conducts a biennial survey, the Civil Rights Data Collection (CRDC), which gathers data on areas such as student demographics, who enrolls in math and science courses, and students who are subjected to disciplinary actions such as expulsions and suspensions. The CRDC helps the Department assess whether public schools are complying with federal anti-discrimination laws and provides data for policymakers, schools, and members of the public.

In addition, the U.S. participates in multiple international comparative education attainment assessments. TIMSS (Trends in International Mathematics and Science Study), for example, is administered by the International Association for the Evaluation of Educational Achievement and assesses how American students compare to international counterparts in science and mathematics. TIMSS also analyzes performance by different demographic groups. TIMSS is administered to a representative sample of fourth, eighth, and twelfth graders. Another important international study the U.S. participates in is the Organisation for Economic Co-operation and Development (OECD)'s Programme for International Student Assessment (PISA). PISA assesses the performance of 15-year-olds in math, science, and reading in the U.S. and dozens of other countries around the world.

Another way to measure access to STEM education is the demographics of students who take AP examinations. This data is collected by the College Board, the non-profit that administers the APs, and is published for each state and the U.S. as a whole every year (College Board, 2020). The National Science Board's *Science and Engineering Indicators* pulls data from many sources to report on the "state of science" in the U.S., including the availability of AP courses and other trends in mathematics and science. For more on this report, see the DEI in the STEM Workforce section (pp. 24-32).

For data on postsecondary education, a key data source is the Integrated Postsecondary Education Data System (IPEDs), annual surveys conducted by the Department of Education each year from every institution that takes part in government financial aid programs for students. IPEDS data is a benchmark for determining how many students are enrolled in postsecondary education, the number of degrees earned, and other vital information. However, this data has

significant limitations. One factor in the availability of public data on STEM pathways is the 2008 Congressional ban on student-level data in higher education, which inhibits the ability to assess what is occurring in STEM education, especially at the postsecondary level. IPEDs primarily collects and reports data on first-time, full-time, and non-transfer students, reporting in aggregate at the institutional level. However, this means that only a small fraction of enrolled persons in higher education are included in most IPEDs data (Bennett et al., 2020). A bipartisan effort has pushed for repeal of the ban and put forward recommendations for a comprehensive system of data collection (Swing, 2016).

Higher education enrollment and degree attainment are also reported by NSF's *Women, Minorities, and Persons with Disabilities in Science and Engineering*. (For a fuller discussion of various other sources and their strengths and weaknesses, see National Academies, 2018a, especially Chapter 6, "Existing Data Sources and Monitoring Systems," pp. 127-176).

The data produced by the above sources is voluminous. For this reason, this report relies on key publications that synthesize these data sources, including the Education Commission of the States' *Vital Signs*, the National Research Council's *Monitoring Progress toward Successful K-12 STEM Education: A Nation Advancing?* and the National Academies of Sciences, Engineering, and Medicine's *Science and Engineering for Grades 6–12: Investigation and Design at the Center*.

Women

Data Findings

Primary and Secondary School

Among the data included in TIMSS reports is a comparison of the science and mathematics scores of boys and girls in grades 4 and 8. In every edition of the 4th-grade mathematics survey since 1995, boys have scored higher. In 2019, the score difference widened to 11 points, up from 3 points in 1995. Similarly, in 4th-grade science, boys score consistently higher than girls. In 8th-grade mathematics, however, the assessment found no significant difference. For 8th-grade science, 2019 marked the first time there was no significant difference in scores between girls and boys. Previously, boys scored anywhere from 5 points higher, in 2015, to 19 points higher, in 1999 (TIMSS, 2019). The most recent NAEP survey showed similar results to these (NAEP, 2019).

The most recent NAEP science survey from 2015 found no significant difference between the average scores for fourth-grade boys and girls in physical science. For eighth graders, boys scored ahead of girls in all three areas, but generally by narrower margins than in the 2011 assessment (NAEP, 2015). For twelfth graders, boys outpaced girls by eight points in physical science and nine in Earth and space sciences; in life science, there was no significant difference

between the two groups (NAEP, 2015). In the TEL questionnaire offered to eighth graders, girls outscored boys by five points (NAEP, 2018).

2020 AP exam statistics from the College Board showed boys scoring higher than girls in 10 out of 12 STEM subjects. The exceptions were AB Calculus (boys had an average score of 3.04, girls 3.05) and computer science (3.01 and 3.22, respectively). Outcomes were most disparate in Physics 1 (boys 2.76, girls 2.41), Chemistry (2.89 vs. 2.57) and Environmental Science (3.06 vs. 2.76) (College Board, 2020).

College

Women earn approximately 50 percent of STEM bachelor's degrees (WMPD, 2019) and 40% of all STEM degrees (Indicators, 2019). However, numbers of women vary greatly by field. The majority of all degrees (bachelor's, master's, and doctorates) in psychology and biological sciences are held by women, as high as 75% at each level in the case of psychology (WMPD, 2019). In mathematics and statistics, the percentages of women who receive bachelor's, master's, and doctoral degrees declined or remained essentially unchanged between 2006 and 2016 (WMPD, 2019). In 2016, women earned less than 40% of the total degrees across the physical sciences, with higher shares in chemistry (more than 45% of bachelor's and master's degrees) and lower shares in physics (only 19.3% of bachelor's and doctoral degrees and 22.1% of master's degrees).

Two other fields that demonstrate particular male-female disparities are computing and engineering. According to *Vital Signs*, of the 188,623 computing degrees or certificates awarded in 2017, 144,569 (76.6%) went to men and 44,054 (23.4%) went to women. Of the 179,694 engineering degrees or certificates, men earned 137,860, or 76.7%; women 41,834, or 23.3% (Vital Signs, n.d.).

Analysis

The literature on the disparities faced by women and girls in STEM is vast. In the data highlighted in this report, some assessments, particularly at the fourth and eighth grade level, show little difference in performance between boys and girls or suggest that some gaps have narrowed. However, data at the high school and college level continue to show pronounced disparities, especially in fields like computer science, engineering, and the physical sciences.

Research suggests several reasons for these disparities. They include lack of support from teachers and families, lack of mentoring and work-life balance, sexist stereotypes about women's aptitude for STEM, and unconscious or implicit bias (Hill et al., 2010; Corbett & Hill, 2015). While women of color have made gains in STEM fields, especially in psychology and other social sciences, they remain especially under-represented in fields such as computer science and engineering. As recently as 2008, for example, less than 3% of PhDs in computer science and engineering were earned by women of color (Malcom & Malcom, 2011). Research

suggests lack of faculty diversity and the rigid cultures and structures of many academic institutions and departments create atmospheres that are particularly unwelcoming for women from underrepresented minority groups (Malcom & Malcolm, 2011).

One way to draw greater attention to these disparities would be to create a set of national equity indicators, as outlined in the National Academies' 2019 report *Monitoring Educational Equity*. The goal would be to "generate regular reports on the indicators and bring visibility to the long-standing disparities in educational outcomes in the United States and should highlight both where progress is being made and where more progress is needed" (National Academies, 2019, p. 11). The suggested indicators should pay special attention to the intersections that place certain populations—such as women of color—at particular disadvantage.

Underrepresented Groups: African Americans, Hispanics, & Indigenous People

Data Findings

Primary and Secondary School

Disparities between different demographic groups in performance on assessments are apparent as early as fourth grade. According to *Vital Signs*' analysis of NAEP data, in 2019 52% of white 4th-grade students scored at or above Proficient in mathematics, but only 20% of Black, 28% of Hispanic/Latinx, 28% of Native Hawaiian/Other Pacific Islander, and 24% of American Indian/Alaska Native students did. In eighth grade, 43% of white students ranked Proficient or higher, compared to 13% of Black, 19% of Hispanic/Latinx, 21% of Native Hawaiian/Other Pacific Islander, and 15% of American Indian/Alaska Native students. Similar results are documented for both fourth and eighth graders in science (Vital Signs, n.d.; NAEP, 2019). TIMSS results show similar trends.

AP data also reveal significant disparities. In 2012, Black students constituted roughly 15% of high school graduates, but less than 8% of the students who took an AP exam in a STEM subject (Indicators, 2014). Hispanic/Latinx students were 18% of the 2012 graduating class, but 7-15% of those taking AP exams in STEM, depending on the subject (Indicators, 2014). Of all students who graduated high school in 2015, 14% took an AP exam in mathematics and 8% received a score of 3 ("Qualified") or higher. 6% of Black students took an AP math exam and 2% scored 3 or higher; 10% of Hispanic/Latinx students took an exam and 3% received a 3 or higher; 6% of American Indian/Alaska Native students took an exam and 3% scored 3 or higher. The rates for white students are 14% and 9% (Vital Signs, n.d.).

College

Underrepresented minorities are 37% of the college-age population (Vital Signs, n.d.). According to one analysis of 2016 college graduates, underrepresented minorities received 22% of bachelor's degrees in STEM and 9% of doctorates (WMPD, 2019). Hispanics earned 13.5% of

science bachelor's degrees and 10% of engineering ones; African American students earned 9% and 4%, respectively; American Indians or Alaska Natives, 0.5% and 0.3%; and Native Hawaiian or other Pacific Islanders, 0.2% and 0.1% (WMPD, 2019). In computing, underrepresented students earn a total of 24% of computing degrees/certificates; in engineering, 16% (Vital Signs, n.d).

Analysis

For decades, researchers have pointed to the challenges faced by women of color and others who share more than one identity that has historically faced discrimination, such as race, ethnicity, disability status, LGBTQ+ status, and more—what today is often called "intersectionality" (Malcom et al., 1976). The section above details several ways in which African Americans, Hispanics, and Indigenous people do not have equal access to quality STEM education and how women in particular experience what is called the "double bind" of being a woman and a member of a minority group in science (Malcom et al., 1976). As of 2014, more students of color (including African American/Black, Hispanic/Latinx, Asian, and Indigenous) than white students were enrolled in U.S. public primary and secondary schools (National Academies, 2019b). The fact that public schools are now majority minority—and the disparities described above and their intersections—means that ensuring equitable access to quality STEM education is of paramount importance not just for meeting the UNESCO Recommendation's goals, but also for the future of the U.S. scientific enterprise.

Research suggests several reasons behind these achievement gaps. *Vital Signs* points to the numbers of students who do not complete high school or college. 84.1% of the 2014-15 high school graduation class received their diplomas. Of high school graduates who enter a four-year degree program, only about five out of eight (62.4%) graduate, and only 39.3% of high school students who begin a two-year associate's program complete it (Vital Signs, n.d.). However, as a 2016 National Academies report indicates, some of this data may be misleading, as many of today's students take less traditional academic paths. "Students are taking complex pathways to earning STEM credentials, often transferring among institutions, entering and exiting STEM pathways at different phases of their studies, and concurrently enrolling at more than one institution…it seems important to consider multiple factors (e.g., student goals, course completion, credit accumulation, time to and credits to degree, retention and transfer rates, degrees awarded, range of access) along with graduation rates" (National Academies, 2016, p. 54).

Why do disparities begin so early? One factor may be limited classroom time spent on science. In 2015, 53% of classes in grades 1-4 spent under three hours a week on science. The amount of time spent on STEM subjects is important because some studies draw connections between elementary school experiences and students' career paths (National Research Council, 2013).

Access to experienced teachers is another factor. In 2015, 47% of white, 46% of Black, and 50% of Hispanic/Latinx 8th-grade students had a science teacher with an undergraduate major in

science. However, a more noticeable gap appears in math: in 2019, 32% of white, 27% of Black, and 30% of Hispanic 8th-graders had a math teacher with an undergraduate major in mathematics. 8th-grade white students are more likely (76%) to have a math teacher with at least six years of experience, compared to 64% of Black students and 67% of Hispanics (Vital Signs, n.d.). This disparity stems from residential segregation and students of color being more likely to attend students with fewer resources (see below).

In high schools, many U.S. students do not have the option to take challenging math and science courses. In 2013-14, 21% of white students attended schools that did not offer calculus, and 14% schools that did not offer physics. For Black, Hispanic, and American Indian/Alaska Native students, these figures are 32%, 25%, and 42% for calculus and 23%, 18%, and 34% for physics (Vital Signs, n.d.). According to a 2016 analysis, only 22% of Indigenous 12th-graders are enrolled in schools that offer computer science classes, and only 14% attend schools where the Computer Science AP class is offered (Vital Signs, 2016). This lack of access in turn is connected to disparities in standardized tests and other assessments.

Black, Hispanic/Latinx, and Indigenous students are also more likely to attend schools with fewer resources. In 2015, 65% of white 8th-graders had science teachers who reported having all or most of the resources they needed. The percentage was 50% for Black 8th-graders and 59% for Hispanic ones. As of 2015, 88% of white 8th-graders attended schools that had science laboratories; 82% of Black and 86% of Hispanic students did. However, not all of those labs are well equipped. According to a 2011 Department of Education survey, 62% of white eighth-graders attended schools that reported lab supplies and materials were available "to a large extent." This figure shrunk to 55% for Black students and 58% for Hispanic students (Vital Signs, n.d.).

The persistence of racially segregated schools, with white students often concentrated in schools with more resources and students of color concentrated in schools with fewer resources, undergirds these disparities. As a 2019 National Academies report articulates, "Even though courts acted to dismantle formerly lawful segregation [since the 1950s], segregation has persisted in ways that did not reach the legal threshold for intervention and in the legally permissible form of segregation resulting from factors such as housing restrictions and local zoning ordinances. Consequently, racially segregated schools, separate and unequal, still exist today" (National Academies, 2019b). In fact, the number of segregated schools appears to be increasing. A 2016 Government Accountability Office (GAO) report found that the number of "high-minority enrollment schools" (those where at least 75% of students are Black or Hispanic/Latinx) rose to 16% in 2013-14, from 9% in 2000-2001 (GAO, 2016).

A closely related issue is socioeconomic status. A 2015 study found that the highest-poverty school districts obtain around 10% less funding (which translates to $1,200 per student) from state and local governments than the wealthiest school districts. Districts that serve the most students of color obtain 15% less funding (translating to $2,000 per student) than school districts with the largest proportion of white students (Ushomirsky & Williams, 2015). Schools

that are under-resourced are less likely to be able to employ experienced teachers, offer as many STEM courses, or afford high-quality equipment.

Poorer students of all backgrounds, including from rural areas, are less likely to have access to advanced STEM courses such as APs. A 2012 survey found "the average number of both mathematics and science courses available at low-poverty schools and suburban and urban schools was about twice those available at high-poverty schools and rural schools" (Indicators, 2014). NAEP data shows lower science scores for 8th-graders and 12th-graders who are eligible for free or reduced-price lunch. Within each demographic group, students not eligible for free or reduced-price lunch performed between 13 and 27 points higher on the NAEP Science assessment than students from the same group who were eligible (National Academies, 2019b).

Practices within schools may also reinforce existing disparities. One example is "tracking," the practice of putting students into different classes (such as basic or advanced) based on their perceived ability in a subject. Tracking can amplify existing societal inequalities, leaving students of similar race, sex, socio-economic status, or perceptions about learning abilities concentrated in less rigorous classes. Once placed on these tracks, it becomes harder for these students to catch up with their peers. "When students who experience difficulty are provided with an inferior curriculum, they are certain to fall farther behind" (Burris et al., 2009).

The COVID-19 pandemic has also highlighted disparities in access to technology and advanced math and science courses. Within just a few weeks after the pandemic forced schools to switch to remote learning, teachers with greater numbers of low-income students were already more likely to cite students' lack of access to technology as a "major challenge" (Herold, 2020). Districts that are in rural, urban, or high-poverty areas are less likely to be able to provide online learning to all students (Herold, 2020).

The economic consequences of COVID-19, such as increased unemployment, disproportionately affect people of color and may lead to disruptions in children's lives such as food insecurity and housing instability (Mitchell, 2020). These effects can have serious long-term impacts on children, such as lower educational attainment (Mitchell, 2020). By exacerbating existing inequalities, COVID-19 may make access to quality STEM education for all American children even more challenging.

An important action for the U.S. Departments of Justice and Education should be to make more frequent use of sources such as the Civil Rights Data Collection to keep track of disparities and monitor school segregation, with a particular eye to how the pandemic has affected these trends. While written in 2016, the GAO report *K-12 Education: Better Use of Information Could Help Agencies Identify Disparities and Address Racial Discrimination* provides helpful guidance.

People with Disabilities

Data Findings

Primary and Secondary School

NAEP data allows comparison between students with and without disabilities. For the 4th-grade mathematics assessment in 2019, the average score gap between the two groups was 31 points (245 for non-disabled students, 214 for disabled ones). In 2003, the gap was 23 points (237 for non-disabled students, 214 for disabled ones), meaning that scores for disabled students have stagnated and that the disparity has widened over time (NAEP, 2019). The score gap for 8th and 12th grade was similarly wide: 40 and 35 points, respectively (NAEP, 2019). In science, in 2015 18% of disabled 4th-graders scored "Proficient" or above, compared to 41% among non-disabled students. Similar gaps were found in 8th (11% vs. 37%) and 12th grade (9% vs. 23%).

Disabled students are estimated to represent approximately 14% of public school enrollment and 12% of secondary school enrollment, but just 1% of students who take AP classes (Schaeffer, 2020; DeWitt et al, 2020). The author of this section was unable to find sufficient data to assess any disparities in disabled students' performance on AP STEM exams.

College

In 2016, nearly 20% of undergraduate students reported having some kind of disability. Because definitions of disability vary and the wording of surveys that measure disability (such as the American Community Survey) have changed over time, it is difficult to assess trends using the available data about disability. According to one study, 28% of undergraduate students with disabilities were enrolled in STEM courses, a rate similar to non-disabled students (WMPD, 2019).

Analysis

As the above data show, disparities are apparent in performance between disabled and non-disabled students in STEM subjects and enrollment in advanced STEM courses. However, the lack of disaggregation among disabilities makes interpreting the data challenging. As with any group, people with disabilities are not monolithic, and further data could better establish whether students with certain kinds of physical disabilities, for example, perform differently than students with cognitive disabilities.

One potential solution is to expand major federal data sources such as IPEDS to include data not just about race, ethnicity, and gender, but also about disability and issues such as socioeconomic status. More data will permit greater understanding of questions such as how long disabled people take to complete courses and degrees, how many STEM educators and students are disabled, and more (for more specifics about how this proposal could be implemented by the U.S. government or a contractor, see National Academies, 2018a).

Even without this data, several reasons why people with disabilities do not currently enjoy equitable access to quality STEM education are clear. Studies have demonstrated the role of factors such as limited access to STEM courses, a lack of mentorship opportunities, and a dearth of the personalized support that many students with disabilities need (Dunn et al., 2012). Other studies point to the roles of a rote, textbook-based teaching style and lack of skills, knowledge, and effective teaching strategies among science teachers who work with students with disabilities (Lee & Erdogan, 2007; Mumba & Chitiyo, 2008).

Research also suggests that trends among students with disabilities mirror disparities among other marginalized populations in STEM. Female STEM majors with disabilities are under-represented across two-year, four-year, and other postsecondary institutions. However, disabled students from poorer backgrounds may be more likely than non-disabled students to pursue STEM majors. "People with disabilities from lower-income backgrounds seemed to make greater efforts on increasing employment opportunities compared to their peers from higher-income backgrounds. Many people with disabilities, particularly those who are economically disadvantaged, attempt to participate in STEM workforce occupations in spite of the challenges often faced in their learning process" (Lee, 2014, p. 268). This finding indicates the importance of providing academic and career resources that meet disabled students' needs (Lee, 2014).

LGBTQ+ Populations

Data Findings

Insufficient data are readily available to assess disparities experienced by LGBTQ+ students in STEM at the K-12 level. A key reason is that NCES data does not currently include information about LGBTQ+ status (American Educational Research Association (AERA), n.d.).

Analysis

Research suggests that LGBTQ+ students are more likely than the national average to drop out of high school. Of those who drop out, many cite bullying and harassment from other students as the principal reason. According to research from 2012-2014, as many a third of LGBTQ+ students reported skipping at least one day of school in the past month due to fears about their safety (AERA, n.d.). On the other hand, other studies suggest that bullying may actually lead some LGBTQ+ students to focus more on academic achievement (National Academies, 2020b).

Another factor that may impede STEM achievement for LGBTQ+ students of color is that they are more likely to be subjected to disciplinary action in school. "Qualitative studies have documented the ways that gender, race, and sexuality intersect to disadvantage youth who are gender nonconforming: for example, Latinx girls whose gender expression is masculine may be perceived by teachers as threatening, while Black boys whose gender expression is feminine

may be disciplined for their dress, behavior, or expression" (National Academies, 2020b, p. 234).

At the university level, available data suggests that LGBTQ+ students may be more likely to leave STEM fields than their non-LGBTQ+ peers. A 2018 study in *Science Advances* reported that 7% fewer LGBTQ+ sexual minority students remained in STEM fields than non-LGBTQ+ students after four years of college. After controlling for other factors, the percentage rose to almost 10% (Hughes, 2018). Another study found that men in same-sex couples were 12% less likely to finish an undergraduate degree in STEM than men in different-sex couples. However, the author found no such gap when comparing women in same-sex and different-sex relationships (Sansone & Carpenter, 2020).

More data is needed to be able to draw firm conclusions. However, the studies cited above suggest that disparities may be greater for people within the LGBTQ+ community, such as LGBTQ+ people of color, with intersecting, historically marginalized identities. The finding that women in same-sex couples are more likely than men in same-sex couples to complete a STEM bachelor's degree may be due to stereotypical perceptions about masculinity embedded in the field (Hughes, 2018; Sansone & Carpenter, 2020).

In order to generate better data, the government should recognize that current federal surveys often use inconsistent terminology and provide little information about transgender and intersex people. LGBTQ+ communities should not be viewed monolithically and research should acknowledge the differences among individuals and groups often placed under one umbrella (National Academies, 2020b). Including questions about sexual orientation and gender identity in the various surveys described in this report will help foster a better understanding of the diverse LGBTQ+ experiences with access to STEM education, as well as intersections with other identities, such as race or disability, that affect the experiences of LGBTQ+ individuals (National Academies, 2020b; AERA Research Recommendations, n.d.).

Again, Fostering a Culture of Respect

One area that is beyond the scope of this report but deserves mention is the connection between DEI efforts and the responsibilities of researchers. Too often in U.S. history, from the exploitation of Indigenous traditional knowledge to medical experimentation on African Americans, scientists have failed to respect the rights of marginalized populations (Washington, 2006; Hansen, 2018). This history and the concomitant lack of trust in science and scientists poses a significant challenge for communicating with the public about the COVID-19 vaccines and other issues where such trust is essential.

A related issue, also beyond the scope of this report but one that deserves brief mention here, is the lack of diversity among those who develop and make decisions about the implementation of new technologies. Research suggests a relationship between the largely white and male workforce of fields such as artificial intelligence and the development of technologies that

reinforce historical discrimination, such as facial recognition tools that disproportionately fail to recognize people of color or risk assessment tools that pinpoint criminal defendants from minority groups as "higher risk" to commit further crimes (West et al., 2019; Schwartzappel, 2019). These two examples highlight the importance of assessing the impacts of science on marginalized populations before new technologies enter into wide use.

Advancing diversity, equity, and inclusion in science means building a culture of respect for all. This effort will require an awareness of past wrongs, humility and a willingness to listen on the part of scientists, and a clear-eyed understanding by decision-makers of the promise and peril inherent in new scientific discoveries.

Recommendations

22. **Develop a national set of educational equity indicators, as outlined in the National Academies' 2019 report** *Monitoring Educational Equity***.**

23. **Enhance U.S. government monitoring of educational disparities.**

24. **U.S. government data collection should include more disaggregated data about disability to allow for more nuanced analysis and targeted interventions.**

25. **Expand and revise federal data collection efforts to include more information about sexual orientation and gender identity.**

26. **Construct a student-unit data system that would allow for increased understanding of how various subgroups are served (or not served) throughout the broader STEM talent development pathways.**

Scientific literacy/public understanding of science

The UNESCO Recommendation

> "Member States should lend their support to all educational initiatives designed to… strengthen all sciences, technology, engineering and mathematics education, in schools and other formal and informal settings." (Recommendation III, 14(a))

A Note about Data and Definitions

The data in this section are drawn primarily from the NSF *Science & Engineering Indicators* series of reports, Pew surveys, and scholarly journal articles.

Data Findings

Where does the public get its information?

Within the NSF *Science & Engineering Indicators* series, researchers have been surveying the American public's understanding of basic scientific concepts for a few decades now. The series typically takes place every two to three years and approximately 2000 American adults are surveyed each time. Survey questions pertaining to public understanding tend to focus on the physical and biological sciences. For example, in 2018, 46% of those surveyed answered correctly that "Electrons are smaller than atoms" (Indicators, 2020). During the same year, 50% of those surveyed correctly indicated that it is false that "Antibiotics kill viruses as well as bacteria." A 2019 study by the Pew Research Center indicates that there may be an important connection between scientific knowledge and education level; this was assessed through a 10-question survey on a range of scientific topics including antibiotic resistance and how the scientific process works (Kennedy & Hefferon, 2019).

An article by Falk and Dierking in *American Scientist* (2010) included a figure showing that, on average, only about 5% of an American's lifetime is spent in the classroom and only a small fraction of that is spent on science education. A 2009 report published by the National Academies Press considered all the "places" where science learning occurs, including science centers, zoos, aquariums, botanical gardens, and planetariums (National Research Council, 2009). This is all part of what is called informal science education (Sacco et al., 2014).

The American public primarily obtains its information about science and technology from the Internet and television. "In 2018, 57% of Americans cited the Internet as their primary source of S&T information" (Indicators, 2020). This is consistent with the general trend towards the public obtaining a greater amount of its information from the Internet during the 21st century. According to a 2017 Pew Research Center study of Americans, 54% of survey participants indicated that their main source of science news is from a "general news source" (Gottfried & Funk, 2017). Interestingly, just 28% of those surveyed indicated that "general news outlets get the facts right about science almost always or more than half of the time" (Gottfried & Funk, 2017).

Methods for communicating science

There are many methods for communicating scientific information, including through different media platforms such as newspapers, radio, television, and the Internet. While intermediaries (i.e., not scientists themselves) often convey scientific information, scientists frequently make use of some of these outlets themselves (e.g., a biologist hosting a blog or an online chat). Moreover, scientists often take part in community events such as visiting a local school or museum.

There are many target audiences for scientific information such as professionals (e.g., physicians), policymakers, and the public. The level of complexity and depth of scientific information shared is usually tailored toward the target audience. For example, a scientific

hypothesis is likely to be presented in much more technical detail in a scholarly journal article when the assumed audience is other scientists as compared to a discussion of the hypothesis during an interview with a journalist.

Increasingly, scientists are using social media to communicate their science to diverse audiences. A survey conducted in 2015 found that 24% of scientists associated with the American Association for the Advancement of Science have blogged about science and that 47% have used social media to discuss or follow science (Pew, 2015b).

Analysis

Science literacy is associated with overall literacy. There is a large body of literature on strategies to improve general literacy as well as specific literacy skills, such as health literacy or science literacy. Authors of a review of literature on the provision of science experiences to increase science literacy published between 2007 and 2017 concluded that there is a lack of studies related to teacher research experiences for K-12 teachers and subsequent impact of those practices (Krim et al., 2019).

In terms of scientists' communication with the public, many professional organizations have professional codes of ethics that address the reporting of research results. One example is the American College of Epidemiology, which states "All research findings and other information important to public health should be communicated in a timely, understandable, and responsible manner so that the widest possible community stands to benefit" (American College of Epidemiology, 2000). This ethical guideline is further clarified: "epidemiologists should strive to ensure that, at a minimum, research findings are interpreted and reported on accurately and appropriately. The goal should be to communicate research findings in ways that allow full use of the information for the public good."

The challenge among scientists, generally, is a lack of training in how to communicate their science. Alan Alda Center for Communicating Science, housed at Stony Brook University, provides an example of an academic center dedicated to empowering scientists to more effectively communicate and build trust with diverse audiences, including non-scientists. In addition to workshops and other professional development opportunities, the Center offers a Graduate Certificate and also a Masters in Science Communication.

Recommendations

27. **National education standards and guidelines should be updated to reflect the most recent pedagogical, evidence-based understanding of science literacy and how best to achieve it at all levels of education and within broader society.**

28. **Graduate programs should include elements in the curriculum about scientific communication for various audiences, including the public; this should be**

offered/could be considered for undergraduate programs as well.

29. **The U.S. government and scientific institutions should encourage and recognize, such as through additional funding, awards, or merit-based recognition, time and expertise devoted by scientists to public communication of science.**

30. **With adequate resources provided by the US government, federal employees and those funded by federal sponsors should be encouraged to take training related to scientific communication and be encouraged to clearly and consistently communicate with the public.**

5. Freedoms, Rights, and Responsibilities of Researchers

The Recommendation articulates eight broad "responsibilities and rights of scientific researchers" which, when viewed as a whole, encompass both traditional ethical responsibilities of scientists as well as broader social responsibilities. According to AAAS, "Scientific freedom is the freedom to engage in scientific inquiry, pursue and apply knowledge, and communicate openly" (AAAS, 2010). Scientific freedom can include the ability to undertake scientific activities without the threat of political or other forms of interference. At times, a government official, for instance, might seek to limit the ability of scientists to conduct their research or share their findings openly. But this can be problematic, especially when such restrictions could detrimentally impact the public's well-being.

The main focus of this section is to address some of the most pressing ethical and social responsibilities of scientists, while recognizing that laws of the United States as well as codes adopted by diverse scientific disciplines recognize specific ethical responsibilities of scientists, but nowhere have the social responsibilities of scientists been specifically identified. Among the responsibilities that scientists have are to respect and protect the rights of human participants in research (Common Rule, 2018; Belmont Report, 1979) and to adhere to ethical guidelines and regulations pertaining to the use of animals in research (Animal Welfare Act, 1966; Public Health Service Policy, 2015). Yet the obligations that scientists have to research subjects will not be a focus in this report.

A 2009 report published by the U.S. National Academy of Engineering recommended that "Educational institutions and [government] agencies that support ethics education should encourage and reward programs that…teach the social responsibilities of science and engineering…and that integrate the issues of social responsibility and [the responsible conduct of research]" (p. 38). Almost ten years later, the National Science Foundation's Strategic Plan for 2018-2022 recognized the value of a STEM workforce "equipped with up-to-date knowledge and the experience needed to address society's current and future challenges" (p. 19).

Ad hoc research in the United States has addressed the question of the social responsibilities of scientists and engineers in specific fields. For example, a study by Corley et al. (2016) of 444 scientists working in the realm of nanotechnology indicated that respondents had a "moderate level of social responsibility about their research." More recent studies have focused specifically on the views of engineering students concerning their social responsibilities, and attempts have also been made to assess student attitudes regarding their social responsibilities as future professionals (Lathem et al., 2013; Schiff et al., 2020).

AAAS defines scientific responsibility, a concept related to social responsibility, as "the duty to conduct and apply science with integrity, in the interest of humanity, in a spirit of stewardship for the environment, and with respect for human rights" (AAAS, 2010). Socially responsible science thus has aims that include but go beyond producing accurate scientific knowledge, furthering various social values. AAAS is currently undertaking a global study to determine what

scientists and engineers believe to be their social responsibilities, the sources of their views, and what influences their ability to exercise their responsibilities. The study includes a U.S.-focused component, one aim of which is to inform future policy deliberations about the social responsibilities of scientists. In the meantime, whether and the extent to which scientists have responsibilities that go beyond their ethical responsibilities to research subjects, colleagues and others directly within their sphere, along the lines of the responsibilities identified in the UNESCO Recommendation, remains a topic of debate and discussion.

Reproducibility

The UNESCO Recommendation

The UNESCO Recommendation calls on member countries to create appropriate means to address scientific ethics, such as promoting researchers' awareness of professional ethics, conflict of interest, and the potential ramifications of their work (Recommendation II, 5(d); Recommendation III, 14(c), (d)(ii)).

A Note about Data and Definitions

As used here, the term scientific reproducibility includes the following components (list adapted from Prager et al., 2019):

a) *Methods reproducibility*—complete and transparent reporting of information required for another researcher to repeat protocols and methods (Goodman et al., 2016), including specific information on the reagents used and how those reagents were authenticated.
b) *Results reproducibility*—independent attempts to reproduce the same or nearly identical results with the same protocols in a different laboratory.
c) *Rigor*—applying the scientific method in a manner designed to ensure an unbiased experimental design, analysis, interpretation, and reporting of results.
d) *Transparency*—making all of the methodology, including the experimental design, reagents, data collection, coding, analysis, and tools used in data analysis, clearly visible to all readers, taking into account necessary protections for classified, confidential and/or personal information.
e) *Randomization*—the random allocation of participants/subjects to different experimental conditions or the order of sample collection to minimize the possibility of subjective influence in the assignment of subjects or unmeasured variables that might influence the outcome.
f) *Blinding*—the investigator and research team are unaware of the group to which the subject was allocated, from the beginning of the study through analysis completion.

Additional significant components of an effective and responsible reproducibility framework include records and data management, preventing inappropriate data manipulation, and systems for reporting concerns about scientific misconduct.

Data Findings

In the past two years, the US National Academies of Sciences, Engineering, and Medicine have held multiple workshops on the topic that brought together many stakeholders to discuss the topic of scientific reproducibility. The proceedings of this most recent workshop outline numerous recommendations, several of which form the basis of the recommendations herein, as well as the sources of many of the citations (National Academies, 2020a).

Analysis

Reproducibility has come to be seen as having a fundamental role in scientific discovery. This viewpoint was expressed succinctly by the philosopher of science Karl Popper in his classic book The *Logic of Scientific Discovery*, who stated that "non-reproducible single occurrences are of no significance" (Popper, 1959). A more nuanced view was presented more recently by Sabina Leonelli (2018), who argues that "the uncritical pursuit of reproducibility can in some cases be misleading and potentially damaging to scientific advancement." She notes, for example, that there are natural phenomena that are of significant scientific interest precisely because they are rare. Furthermore, different fields (such as the humanities and social sciences) can have varying notions of reproducibility, and reproducibility requirements can be one of many ways to produce reliable research (Leonelli, 2018).

Until fairly recently, there was a widely held belief that science is inherently self-correcting, and that important scientific discoveries would be replicated in the course of carrying out further research which builds upon them. As a result, those discoveries which are not found to be reproducible would be identified and discarded. However, a series of high impact publications in the past decade has raised serious questions about this set of assumptions, documenting a striking lack of reproducibility of studies in the biological sciences, including cancer research (Begley & Ellis, 2012), drug discovery (Prinz et al., 2011), and behavioral sciences (Andrews et al., 2018).

Collectively, these data demonstrate that the lack of reproducibility in science is a serious issue that cuts across multiple scientific domains, and one that requires a response from multiple stakeholders, including educational Institutions, funders of research, including government and private, as well as practicing scientists and scientific societies. In response to these findings, each of the different stakeholders has in fact responded with various initiatives to improve reproducibility, including governments (Landis et al., 2012), and scientific journals (Prager et al., 2019).

Multiple strategies exist that would support reproducibility. One important strategy is mandatory training for students and junior researchers and, optimally, for all scientific mentors, including established investigators. Participation of senior investigators is important to increase the effectiveness of training for junior investigators, to ensure best practices are embraced and

reinforced, and because in practice senior investigators are most commonly the people who provide training on these topics, albeit informally (Begley et al., 2015).

Another effective strategy for increasing reproducibility is to support independent replication of key experimental findings. For practical reasons, this is not possible nor recommended for every publication. However, it may be appropriate for particularly controversial or novel findings of broad significance, as well as for translational studies that are intended to provide support for future clinical trials. The recent National Academies workshops suggested that independent replication may be warranted if the results of the original study are to be used in making decisions of consequence (e.g., policy, clinical, or investment decisions); if the original study produced controversial or unexpected results; if the original study is flawed (e.g., design, methods, analysis); or if "the costs of replication are offset by the potential benefits for science and society" (National Academies, 2020a). Notably, an analysis of the problem indicates that the cumulative (total) prevalence of irreproducible preclinical research results in approximately $28 billion spent per year in the U.S. on preclinical research that is not reproducible (Freedman et al., 2015). The NIH Somatic Cell Genome Editing program has incorporated a requirement for independent replication as a condition for progressing from one stage of funding to a second stage, and funds independent animal testing centers for the purpose of replication (Saha et al., 2021).

Another strategy is the use of checklists (for an example, see Nature Publishing Group, 2015), which facilitates standardization of reporting and also emphasizes best practices for the design of experiments to reduce bias and facilitate reproducibility. While this checklist is for publication in a scientific journal, it can be adapted for other uses, such as in applications for research funding, or incorporated into the evaluation of ongoing research.

In the clinical research sphere, in particular, registration of experiments can serve not only to reduce duplicative research, but also to increase the quality of preclinical data that is the basis of subsequent drug development and clinical trials. One example of a site to register preclinical studies is https://preclinicaltrials.eu/. While much of the focus of preregistration of studies has been on preclinical and translational research, the general approach may be applicable to other scientific fields that involve hypothesis testing (Chambers et al., 2014). Admittedly, however, this approach is not applicable to basic or discovery research.

Scientific journals serve a vital function in the implementation of requirements and standards for reporting not only research findings, but the research materials, data and analysis that underpin those findings. In recognition of that role, in December 2017, a working group of journal editors in the life sciences and other experts in reproducibility came together to elaborate minimum standards intended to enhance transparency in reporting (Chambers et al., 2019). Such standards have the potential to contribute to reproducibility and are relevant across the scientific disciplines beyond the life sciences. The "FAIR Guiding Principles for scientific data management and stewardship" is an example of such standards that apply across

disciplines, aiming to improve the Findability, Accessibility, Interoperability, and Reuse of digital assets (GO FAIR, n.d.).

Recommendations

31. Institutions should require training in scientific reproducibility for researchers at all levels, including the utilization of checklists to facilitate best practices in experimental design, reporting of scientific experiments, data management and archiving.

32. For funders: Provide funding for independent replication of a limited number of critical finding studies.

33. Consideration of a registry for at least some preclinical animal studies that are intended to support drug development and clinical trials.

34. Scientific data and metadata should be generated and maintained according to the FAIR Principles (Findability, Accessibility, Interoperability, and Reuse of digital assets).

Bias

The UNESCO Recommendation

"[I]n order to remediate past inequalities and patterns of exclusion, [Member States should] actively encourage women and persons of other under-represented groups to consider careers in sciences, and endeavour to eliminate biases against women and persons of other under-represented groups in work environments and appraisal." (Recommendation III, 13(c))

A Note about Data and Definitions

The data from this section are from peer-reviewed literature and federal agencies.

Data Findings

Evidence-based medicine requires valid evidence upon which to make informed decisions. Research abuses against under-represented groups and people of color have led to mistrust of researchers and reticence to participate in medical research. The NIH Revitalization Act of 1993 mandated appropriate inclusion of women and minorities in all NIH-funded research (NIH, 2017).

Analysis

A review of National Cancer Institute (NCI)-sponsored clinical trials found that less than 2% of the NCI clinical trials focused on any racial/minority population as their primary emphasis. Other findings included: most minority racial/ethnic groups are under-represented relative to their burden of cancer in the population; barriers to enrollment in cancer clinical trials persist, including mistrust, costs, transportation, differences in cultural perspectives, lack of awareness in available trials or clinical trials as a therapeutic option; physician neglect in inviting patients to consider participation in a clinical trial; linguistic barriers and (English) language proficiency; and differences in culture and cultural considerations (Chen Jr. et al., 2014).

In a study of racial/ethnic minority enrollment into HIV preventive vaccine trials in the US conducted from 2002-2016, researchers found that, although there has been an increase in participation by racial/ethnic minority groups, participation still does not proportionally reflect the number of new HIV cases in racial/ethnic minorities (Huamani et al., 2019). A comparison with the demographic subgroups of participants enrolled in clinical trials of novel drugs approved in 2018 (U.S. Food and Drug Administration, 2019) compared with U.S. Census data reveals under representation of Black or African Americans, Hispanics, and people aged 65 and older in clinical trials relative to their distribution in the US population (U.S. Census Bureau, 2019). In sum, although statistics are improving, racial/ethnic minorities remain underrepresented in medical research.

Recommendations

35. **The U.S. government should track participation by race/ethnicity and other demographic features in federally funded research.**

36. **Require stakeholder engagement in publicly funded medical research.**

37. **The federal government should consider funding research with underrepresented groups to understand their concerns related to research participation.**

Scientific integrity

The UNESCO Recommendation

The UNESCO Recommendation calls on member countries to ensure that:

> "In order to have a sound science, technology and innovation system integrated to their effort, Member States should establish and substantially strengthen human and institutional capacities, including by…establishing suitable means to address the ethics of science and of the use of scientific knowledge and its applications, specifically through establishing, promoting and supporting independent, multidisciplinary and pluralist ethics committees in order to assess the relevant ethical, legal, scientific and social issues related to research projects involving human beings, to provide ethical

advice on ethical questions in research and development, to assess scientific and techno- logical developments and to foster debate, education and public awareness and engagement of ethics related to research and development." (Recommendation II, 5(d))

"Member States should have regard for the fact that effective scientific research calls for scientific researchers of integrity and intellectual maturity, combining high, intellectual qualities and respect for ethical principles." (Recommendation III, 12)

"Member States should lend their support to all educational initiatives designed to… incorporate or develop in each domain's curricula and courses the ethical dimensions of science and of research." (Recommendation III, 14(c))

[See also Recommendation III, 14(d)(ii))

A Note about Data and Definitions

The data in this section are primarily from the federal agencies and scholarly journal articles. The definition of research misconduct discussed in this section is from the Office of Science and Technology Policy (OSTP). The definition of responsible conduct of research (RCR) is from the National Institutes of Health (NIH). While some scholars might define the terms "RCR," "research ethics," and "research integrity" interchangeably, others mean different and distinct things by each of these terms. For the purposes of this section, the term RCR will primarily be used.

Behaviors that erode the quality and integrity of research

Many types of behaviors can erode the quality and integrity of research. These include allowing there to be a toxic or disrespectful research environment and sloppy research practices such as failing to record document details related to an experimental setup. Yet at a federal level, policies from agencies tend to focus primarily on a subset of misbehaviors referred to as research misconduct, as well as safeguards against the partisan politicization of federal science.

A common term of art for misbehaviors that do not reach the level of research misconduct is Detrimental Research Practices (DRPs), a phrase used in the National Academies of Sciences, Engineering, and Medicine's *Fostering Integrity in Research* report (National Academies, 2017). Examples of DRPs include exploiting trainees or providing them with inadequate mentoring.

Federal definition of research misconduct

The primary definition of research misconduct at the federal level is from OSTP: "Research misconduct is defined as fabrication, falsification, or plagiarism in proposing, performing, or reviewing research, or in reporting research results" (OSTP, 2000). Fabrication, in this context, refers to "making up data or results and recording or reporting them" (OSTP, 2000).

Falsification involves "manipulating research materials, equipment, or processes, or changing or omitting data or results such that the research is not accurately represented in the research record" (OSTP, 2000). Plagiarism involves the inappropriate reuse of another person's ideas or phrases.

The three behaviors delineated in the OSTP policy, sometimes referred to as FFP, are usually mentioned in the policies of other countries, such as Ireland (Research Integrity National Forum, 2019). Yet depending on the country, other behaviors, such as conflict of interest, might be included within the definition of research misconduct.

Data Findings

Research misconduct occurrence

It is difficult to determine how frequently research misconduct happens in part because there are many reasons why scientists, their organizations, or other entities are reluctant to report it. Also, at least some of the incidents might be handled internal to the research team or within the relevant organization, and not be reported to an external entity (Koocher & Keith-Spiegel, 2010). Moreover, research misconduct can be difficult to detect. However, some of what is known about the frequency of research misconduct emerges from information provided by federal funding agencies.

NSF releases statistics on research misconduct cases within its semiannual reports to the U.S. Congress. For example, it reported that it was aware of 49 research misconduct allegations in 2018 and 38 allegations in 2019 (NSF Office of the Inspector General, 2020). Out of those allegations, there were 14 findings of misconduct in 2018 and 6 findings in 2019. Such statistics provide some sense of scale but only reflect projects being considered for funding or that have been funded by that agency.

The U.S. Department of Health and Human Services (HHS) Office of Research Integrity (ORI) publicly lists cases of misconduct pertaining to research funded by the U.S. Department of Health and Human Services while the "administrative action" against the guilty party is ongoing (ORI, 2021a). However, the case is removed from the list when the administrative action has concluded. Approximately 10 people each year will be found guilty of misconduct pertaining to HHS research.

According to a metanalysis by Fanelli (2009), "on average 2% of scientists admit to have falsified research at least once and up to 34% admit other questionable research practices." Fanelli notes approximately 14% of those surveyed report having observed colleagues who have inappropriately manipulated or fabricated data.

Cost of research misconduct

The costs associated with a case of research misconduct, including the time and effort to investigate it, can be in the hundreds of thousands of dollars (University of Washington Health Sciences/UW Medicine 2014). Michalek et al. (2010) provide a direct cost estimate of a single case of misconduct as being $525,000. If expenses associated with handling cases are combined, misconduct is costing the U.S. millions of dollars per year (Reich, 2010).

Analysis

Government statements on scientific integrity

In November 2020, the Congressional Research Service released a report titled "Federal Scientific Integrity Policies: A Primer." The report provides an overview of scientific integrity policies promulgated by various U.S. federal agencies. Scientific integrity policies are usually different in substantive ways than a policy pertaining to RCR. The former is usually broader in scope, including describing conditions governing the development and communication of scientific information by federal scientist and non-scientist actors at the science-policy interface, whereas the latter more narrowly focuses on research-related matters. In addition, the White House (2021a; 2021b) has recently released memos directing federal action to strengthen scientific integrity and the use of science in decisionmaking. Moreover, the White House has requested of OSTP that it facilitate the creation of "an interagency Task Force on Scientific Integrity of the National Science and Technology Council (NSTC) to review the effectiveness of scientific integrity policies across the Federal Government" (OSTP, 2021).

Federal policies on RCR

Three federal funding agencies have put forward policies on the Responsible Conduct of Research: NSF, NIH, and the U.S. Department of Agriculture (USDA) National Institute of Food and Agriculture (NIFA). The NIH defines RCR "as the practice of scientific investigation with integrity. It involves the awareness and application of established professional norms and ethical principles in the performance of all activities related to scientific research" (NIH, 2009).

The NSF and NIH RCR policies largely apply to trainees (including students and postdocs) funded through certain categories of awards from the agencies. The policy from NSF covers all undergraduates, graduate students, and postdocs funded to conduct research (NSF, n.d.). The policy from NIH largely focuses on trainees as well, but who is specifically required to complete the training is determined by funding mechanism within the agency. The USDA NIFA policy expands the scope of who is required to complete RCR training beyond trainees to include faculty, staff, and others funded by a NIFA award (NIFA, n.d.).

RCR/research integrity curriculum in the U.S.

Although scholars may disagree on the scope and goals of RCR (Kalichman, 2014), the RCR curriculum, in terms of the topics covered, is significantly shaped by ORI and NIH. ORI has

outlined nine core topic areas, including Mentorship, Peer Review, and Data Management, that are often covered in courses or other educational opportunities pertaining to RCR (ORI, 2021b). NIH built on that foundation and expanded on the topics within its RCR policy, adding areas such as "safe laboratory practices" and "the scientist as a responsible member of society" (NIH, 2009). These two branches of HHS have had a significant influence on what academic institutions cover in terms of RCR content.

For approximately a decade, NSF has had a grant program that supports the development and implementation of ethics and RCR educational materials. An earlier iteration of the funding solicitation was entitled Ethics Education in Science and Engineering (EESE) (NSF, 2011). A key aim of the current version of the program, entitled Ethical and Responsible Research (ER2), aims to "produce knowledge about what constitutes or promotes responsible or irresponsible conduct of research, and how to best instill this knowledge into researchers and educators at all career stages" (NSF, 2019).

While many countries (such as Ireland and Australia) have issued reports or statements on the importance of RCR or research integrity, a formal requirement for RCR training appears to be rather rare globally (Research Integrity National Forum, 2019; Australian Government, 2014). Just focusing on the U.S., only a subset of federal agencies requires some form of RCR/research integrity training for researchers that they fund.

Research misconduct in the U.S. and globally

Given the gaps in knowledge about the occurrence of research misconduct, it is difficult to determine how the U.S. compares to other countries. Yet there are some efforts, including in the health sciences, to try to close the knowledge gaps about its prevalence (Artino et al., 2019). Determining where specifically research misconduct is taking place is complicated by the increasing number of international collaborations. Moreover, federal funding agencies within the U.S. and globally adopt varying approaches to disclosure of information pertaining to research misconduct cases.

Recommendations

38. **Federal sponsors should develop or modify funding policies to make clear that all members of a research team should participate in professional development activities including or related to research practice and research integrity.**

39. **Federally-funded academic institutions should include education on the ethics of research in all STEM programs at both the undergraduate and graduate level and develop strategies for transforming institutional cultures to more effectively integrate ethical concerns.**

40. U.S. government agencies, academic institutions, publishers, and scientific organizations should work toward greater alignment of policies on research misconduct and scientific integrity, procedures, and accountability mechanisms, in order to ensure consistent expectations and enforcement across the scientific community.

Quality science

The UNESCO Recommendation

"(a) the following are the recommended responsibilities and rights of scientific researchers:

(vi) to disclose both perceived and actual conflicts of interest according to a recognized code of ethics that promotes the objectives of scientific research and development…" (Recommendation IV, 16 (a)(vi)).

A Note about Data and Definitions

The data in this section are primarily from scholarly journal articles.

Data Findings

Retractions

A retraction refers to a situation in which an already published work is marked by the publisher as "retracted" but remains discoverable. According to an analysis of retractions reported in *Science* magazine in 2018, about half of retractions involve fabrication, falsification, or plagiarism. Another ten percent are the result of "forged authorship, fake peer reviews, and failure to obtain approval from institutional review boards" for research involving human subjects or animals. About 40% of papers are retracted for reasons such as errors, problems with reproducibility, and other issues not considered scientific misconduct (Brainard & You, 2018).

While recognizing that retractions frequently occur for reasons for human error, retractions are often used as an imperfect proxy, among many other measures, for determining the quality of scientific research being conducted. The frequency with which retractions occur may be a partial gauge for whether scientists are upholding proper research practices. Retraction Watch (retractionwatch.com) is a website that draws attention to cases where journals or other entities have removed papers from the published literature. It maintains a "Leaderboard" of the individuals who have the most retractions.

In 2011, Van Noorden noted, "In the early 2000s, only about 30 retraction notices appeared annually. This year, the Web of Science is on track to index more than 400…even though the total number of papers published has risen by only 44% over the past decade" (Van Noorden, 2011). It can be difficult to determine why the increase occurred but some possible explanations include a growing number of journals, a potential increase in author misbehavior, or increased diligence by journals in seeking to identify problems in published works. Brainard and You claim that retractions are "relatively rare: only about four of every 10,000 papers are now retracted" (Brainard & You, 2018). They remark that the sheer number of retractions continues to grow, which may indicate that journals are implementing better oversight mechanisms.

Fang et al. (2012) conducted a review of references in the PubMed database retracted as of May 2012 and found that only 21.3% were retracted because of error. More than two-thirds (67.4%) were retracted because of scientific misconduct including fraud, duplicate publication, and plagiarism. A retraction, especially when it is tied to an underlying form of misbehavior, can be an indication that resources have been wasted. Stern et al. (2014) found in their study that "papers retracted due to misconduct accounted for approximately $58 million in direct funding by the NIH between 1992 and 2012."

Publication bias

Different forms of bias can impact the publication process in a variety of ways. For example, there is a large collection of anecdotal evidence that journals are reluctant to publish negative results (DeVito & Goldacre, 2018). This form of bias is one of driving forces behind efforts to require the registration of clinical trials and the push for more open sharing of research data (Wieseler & McGauran, 2020). Measures such as clinical trial registration and open data sharing can provide a fuller picture of the types of research studies being conducted as can such efforts as that led by RIAT (Restoring Invisible and Abandoned Trials) which aims to tackle bias in the way research is reported, specifically by offering a methodology by which the record can be "responsibly corrected" by correcting the misreporting of trials that are published either inaccurately or incompletely, and publishing trials that are otherwise unpublished (RIAT, n.d.).

Analysis

Various forms of bias can detrimentally impact the peer review process (Haffar et al., 2019), including when a reviewer has a conflict of interest (DiDomenico et al., 2017), or a journal's editor process (Gottlieb & Bressler, 2017). Authors' conflicts of interest (COI) can also affect the peer review process if, for example, they are permitted to recommend their own peer reviewers. Moreover, studies have examined whether revealing the authors' COI changes the review process. According to John et al. 2019's study of 1480 manuscripts, "providing reviewers with COI information did not have a significant effect on their manuscript quality ratings."

Efforts are being made to address these challenges through clarification of concepts and simplification of processes. Broadening understandings of what interests may be relevant to disclose, the International Committee of Medical Journal Editors has recently updated its disclosure form to refer to "disclosure of interests," and *Science* magazine refers to "competing interests." At the same time a product called Convey, developed by the American Association of Medical Colleges, aims to simplify the disclosure process by serving as a database for disclosures that can be shared with funders, journals, and institutions, avoiding the need for regular and tedious repetition in reporting of interests.

Since publishing is often an international endeavor, it can be difficult to isolate one country's practices from other countries. Yet there is some basis for comparison. For example, in a study of papers that were retracted or corrected in 2010-2011, Fanelli et al. (2015) found that in comparison with the US, Australia, Germany, China, South Korea, and Turkey were more likely to host authors of retracted papers, and the Netherlands and France were less likely.

Recommendations

41. The federal government should consider funding further studies on how conflicts of interest impact the publication process and research practices more generally.

Appendix A: List of Recommendations

As a general recommendation addressed to the government, but also interested academics and scientific organizations, we propose the following:

1. **identify the data necessary to establish benchmarks and measure progress in each of the key areas of the UNESCO Recommendation; and**

2. **establish mechanisms for addressing any current data gaps.**

Public engagement in science

3. **The U.S. government should consider strategies and potential funding opportunities to support citizen science projects.**

4. **The U.S. government should study the impacts of citizen science, including on science literacy, public perceptions of science, support for funding of science, and time from discovery to implementation.**

5. **The U.S. government should fund research to establish best practices for public engagement in science.**

Science for Society

6. **Federal agencies should consider allocating additional funding to public interest science, including potentially high-yield projects in mission-driven public-interest research.**

7. **Public funding is needed to support research that explores how, in what circumstances, and with what social impact policy changes have driven public funding into private-interest science.**

8. **Public funders of science and recipients should be encouraged to explore humanitarian licensing options to promote access to and use of scientific and technological innovations by historically disadvantaged populations.**

Trust in science

9. **Federal agencies should consider funding research on what facilitates and erodes trust in science.**

10. **Publicly-employed/-funded scientists should be encouraged and recognized for efforts aimed at cultivating relationships with the public that foster a sense of trustworthiness.**

11. **The science communication ecosystem should work to decouple partisan identities from public science controversies by emphasizing that the issues at stake are not strictly partisan.**

12. **The federal government should consider funding programs that research, monitor, and respond to science mis/disinformation over online platforms.**

Independent science

13. **The U.S. government should better track, analyze, and make public all available data on conflicts of interest and scientific independence in the U.S. federal government.**

14. **The U.S. government should take steps to strengthen federal protections for science and scientists working in policy contexts. Such efforts should include strengthening scientific integrity policies across all federal science agencies, improving consistency in policy and practice across the government, and appointing science agency and White House decisionmakers who can provide strong leadership on independent science.**

15. **To address conflicts of interest in science advice settings, the U.S. government should strengthen its oversight and guidance on conflict of interest in order to create more transparency and accountability around the formation, appointment, activities, and disbanding of science advisory committees.**

Open access and open data

16. **The U.S. government should develop clear guidelines for making federally funded research open access and open data publicly available. The U.S. government should host data on their repositories through a link from research articles.**

17. **Federal sponsors should address inequities associated with costs to researchers of open access publication.**

18. **Research funded publicly should support reasonable costs associated with open access publishing.**

19. **The federal government should fully implement its plans to expand open data initiatives and infrastructure, with a focus on ensuring data is shared in accessible and useful formats and an emphasis on disaggregated demographic data that will enable researchers to better study and identify inequities in government services and public benefits of science.**

Diversity, Equity and Inclusion (DEI) in the STEM workforce

20. **For the U.S. government (including executive leadership and federal science agencies) and funders: make addressing inclusion, equity and discrimination in the STEM workforce a key national priority.**

21. **U.S. government data on the workforce should include more and better information about people from indigenous, LGBTQ+, and disabled identities.**

Access to quality STEM education

22. **Develop a national set of educational equity indicators, as outlined in the National Academies' 2019 report *Monitoring Educational Equity*.**

23. **Enhance U.S. government monitoring of educational disparities.**

24. **U.S. government data collection should include more disaggregated data about disability to allow for more nuanced analysis and targeted interventions.**

25. **Expand and revise federal data collection efforts to include more information about sexual orientation and gender identity.**

26. **Construct a student-unit data system that would allow for increased understanding of how various subgroups are served (or not served) throughout the broader STEM talent development pathways.**

Scientific literacy/public understanding of science

27. National education standards and guidelines should be updated to reflect the most recent pedagogical, evidence-based understanding of science literacy and how best to achieve it at all levels of education and within broader society.

28. Graduate programs should include elements in the curriculum about scientific communication for various audiences, including the public; this should be offered/could be considered for undergraduate programs as well.

29. The US government and scientific institutions should encourage and recognize, such as through additional funding, awards, or merit-based recognition, time and expertise devoted by scientists to public communication of science.

30. With adequate resources provided by the US government, federal employees and those funded by federal sponsors should be encouraged to take training related to scientific communication and be encouraged to clearly and consistently communicate with the public.

Reproducibility

31. Institutions should require training in scientific reproducibility for researchers at all levels, including the utilization of checklists to facilitate best practices in experimental design, reporting of scientific experiments, data management and archiving.

32. For funders: Provide funding for independent replication of a limited number of critical finding studies.

33. Consideration of a registry for at least some preclinical animal studies that are intended to support drug development and clinical trials.

34. Scientific data and metadata should be generated and maintained according to the FAIR Principles (Findability, Accessibility, Interoperability, and Reuse of digital assets).

Bias

35. The U.S. government should track participation by race/ethnicity and other demographic features in federally funded research.

36. Require stakeholder engagement in publicly funded medical research.

37. **The federal government should consider funding research with underrepresented groups to understand their concerns related to research participation.**

Scientific integrity

38. **Federal sponsors should develop or modify funding policies to make clear that all members of a research team should participate in professional development activities including or related to research practice and research integrity.**

39. **Federally-funded academic institutions should include education on the ethics of research in all STEM programs at both the undergraduate and graduate level and develop strategies for transforming institutional cultures to more effectively integrate ethical concerns.**

40. **U.S. government agencies, academic institutions, publishers, and scientific organizations should work toward greater alignment of policies on research misconduct and scientific integrity, procedures, and accountability mechanisms, in order to ensure consistent expectations and enforcement across the scientific community.**

Quality science

41. **The federal government should consider funding further studies on how conflicts of interest impact the publication process and research practices more generally.**

Appendix B: UNESCO Recommendation on Science and Scientific Researchers

Preamble

The General Conference of the United Nations Educational, Scientific and Cultural Organization (UNESCO), meeting in Paris from 30 October to 14 November 2017, at its thirty-ninth session,

Recalling that, by the terms of the final paragraph of the Preamble to its Constitution, UNESCO seeks – by means of promoting inter alia, the scientific relations of the peoples of the world – to advance the objectives of international peace and of the common welfare of humankind for which the United Nations Organization was established and which its Charter proclaims,

Considering the terms of the Universal Declaration of Human Rights adopted by the United Nations General Assembly on 10 December 1948, and in particular Article 27.1 thereof which provides that everyone has the right freely to participate in the cultural life of the community, and to share in scientific advancement and its benefits,

Recognizing that:

(a) scientific discoveries and related technological developments and applications open up vast prospects for progress made possible in particular by the optimum utilization of science and scientific methods for the benefit of humankind and for the preservation of peace and the reduction of international tensions but may, at the same time, entail certain dangers which constitute a threat, especially in cases where the results of scientific research are used against humankind's vital interests in order to prepare wars involving destruction on a massive scale or for purposes of the exploitation of one nation by another, or to the detriment of human rights or fundamental freedoms or the dignity of a human person, and in any event give rise to complex ethical and legal problems;

(b) to face this challenge, Member States should develop or devise machinery for the formulation and execution of adequate policies, that is to say, policies designed to avoid the possible dangers and fully realize and exploit the positive prospects inherent in such discoveries, technological developments and applications,

Also recognizing:

(a) the significant value of science as a common good;

(b) that a cadre of talented and trained personnel is the cornerstone of an indigenous

research and experimental development capability and indispensable for the utilization and exploitation of research carried out elsewhere;

(c) that open communication of the results, hypotheses and opinions – as suggested by the phrase "academic freedom" – lies at the very heart of the scientific process, and provides the strongest guarantee of accuracy and objectivity of scientific results;

(d) the necessity of adequate support and essential equipment for performance of research and experimental development,

Observing that, in all parts of the world, this aspect of policy-making is coming to assume increasing importance for the Member States; having in mind the intergovernmental initiatives set out in the annex to this Recommendation, demonstrating recognition by Member States of the growing value of science and technology for tackling various world problems on a broad international basis, thereby strengthening cooperation among nations as well as promoting the development of individual nations; and confident that these trends predispose Member States to the taking of concrete action for the introduction and pursuit of adequate science and technology policies,

Persuaded that such governmental action can considerably assist in the creation of those conditions which encourage and assist indigenous capability to perform and use the results of research and development in an enhanced spirit of responsibility towards humankind and the environment,

Believing that one of the foremost of these conditions must be to ensure a fair status for those who actually perform research and development in science and technology, taking due account of the responsibilities inherent in and the rights necessary to the performance of that work,

Considering that research and development is carried out in exceptional working conditions and demands a highly responsible attitude on the part of the scientific researchers towards that work, towards their country and towards the international ideals and objectives of the United Nations, and that workers in this profession accordingly need an appropriate status,

Convinced that the current climate of governmental, scientific and public opinion makes the moment opportune for the General Conference to formulate principles for the assistance of member governments desirous of ensuring fair status for the workers concerned,

Recalling that much valuable work in this respect has already been accomplished both in respect of workers generally and in respect of scientific researchers in particular, notably by the international instruments and other texts recalled in this Preamble, and in the annex to this Recommendation,

Conscious that the phenomenon frequently known as the "brain drain" of scientific researchers has in the past caused widespread anxiety, and that to certain Member States it continues to be a matter of considerable preoccupation; having present in mind, in this respect, the paramount needs of the developing countries; and desiring accordingly to give scientific researchers stronger reasons for serving in countries and areas which stand most in need of their services,

Convinced that similar questions arise in all countries with regard to science and scientific researchers and that these questions call for the adoption of common approaches and so far as practicable the application of the common standards and measures which it is the purpose of this Recommendation to set out,

However, taking fully into account, in the adoption and application of this Recommendation, the great diversity of the laws, regulations and customs which, in different countries, determine the pattern and organization of research work and experimental development in science and technology,

Desiring for these reasons to complement the standards and recommendations set out in the laws and decrees of every country and sanctioned by their customs and those contained in the international instruments and other documents referred to in this Preamble and in the annex to this Recommendation, by provisions relating to questions of central concern to scientific researchers,

Having before it, as item 7.4 of the agenda of the session, proposals concerning science and scientific researchers,

Having decided, at its thirty-seventh session, that these proposals should take the form of a recommendation to Member States,

Adopts the Recommendation on Science and Scientific Researchers, which supersedes the 1974 Recommendation on the Status of Scientific Researchers, this 13 November 2017;

Recommends that Member States should apply the following provisions by taking whatever legislative or other steps may be required to apply within their respective territories the principles and norms set forth in this Recommendation;

Also recommends that Member States should bring this Recommendation to the attention of the authorities, institutions and enterprises responsible for the conduct of research and experimental development and the application of its results, and of the various organizations representing or promoting the interests of scientific researchers in association, and other interested parties;

Further recommends that Member States should report to it, on dates and in a manner to be determined by it, on the action they have taken to give effect to this Recommendation.

I. Scope of application

1. For the purposes of this Recommendation:

(a) (i) the word "science" signifies the enterprise whereby humankind, acting individually or in small or large groups, makes an organized attempt, by means of the objective study of observed phenomena and its validation through sharing of findings and data and through peer review, to discover and master the chain of causalities, relations or interactions; brings together in a coordinated form subsystems of knowledge by means of systematic reflection and conceptualization; and thereby furnishes itself with the opportunity of using, to its own advantage, understanding of the processes and phenomena occurring in nature and society;

(ii) the term "the sciences" signifies a complex of knowledge, fact and hypothesis, in which the theoretical element is capable of being validated in the short or long term, and to that extent includes the sciences concerned with social facts and phenomena;

(b) the word "technology" signifies such knowledge as relates directly to the production or improvement of goods or services;

(c) the term "research and development" comprises scientific research and experimental development for which "scientific research" signifies those processes of study, experiment, conceptualization, theory-testing and validation involved in the generation of scientific knowledge, as described in paragraphs 1(a)(i) and 1(a)(ii) above, and thus including both fundamental and applied research; and for which "experimental development" signifies the processes of adaptation, testing and refinement which lead to the point of practical applicability including as innovation;

(d) (i) the term "scientific researchers" signifies those persons responsible for and engaged in research and development;

(ii) on the basis of the provisions of this Recommendation, each Member State may determine the criteria for inclusion in the category of persons recognized as scientific researchers (such as possession of diplomas, degrees, academic titles or functions), as well as the exceptions to be allowed;

(e) the word "status" as used in relation to scientific researchers signifies the standing or regard accorded them, as evidenced, first, by the level of appreciation both of the duties and responsibilities inherent in their function and of their competence in performing them, and, secondly, by the rights, working conditions, material assistance and moral support which they enjoy for the accomplishment of their task.

2. This Recommendation applies with respect to:

(a) all scientific researchers, irrespective of:

(i) the legal status of their employer, or the type of organization or establishment in which they work;

(ii) their scientific or technological fields of specialization;

(iii) the motivation underlying the research and development in which they engage;

(iv) the kind of application to which that research and development relates most immediately;

(v) their professional status or employment status;

(b) technicians, support staff and students supporting and contributing to research and development;

(c) institutions and individuals responsible for research and development and other aspects of science, including such as science education, science communication, regulation and policy, oversight, funding, recruitment, peer review and scientific publishing.

3. In the case of scientific researchers performing research and development on a part-time basis, this Recommendation applies to them only at such times and in such contexts as they are engaged in the activity of research and development.

II. Scientific researchers in the context of national policy-making

4. By the policies they adopt in respect of and touching upon science, technology and innovation; by the way in which they use science and technology in policy-making and more generally; and by their treatment of scientific researchers in particular, Member States should demonstrate and take action such that research and development is not carried out in isolation, but as an explicit part of the nations' integrated effort to set up a society that will be more humane, just and inclusive, for the protection and enhancement of the cultural and material well-being of its citizens in the present and future generations, and to further the United Nations ideals and internationally-agreed objectives, while giving sufficient place to science per se.

5. In order to have a sound science, technology and innovation system integrated to their effort, Member States should establish and substantially strengthen human and institutional capacities, including by:

(a) promoting research and development in all areas of society, funded by public, private and non-profit sources;

(b) equipping itself with the personnel, institutions and mechanisms necessary for developing and putting into practice national science, technology and innovation policies;

(c) strengthening scientific culture, public trust and support for sciences throughout society, in particular through a vigorous and informed democratic debate on the production and use of scientific knowledge, and a dialogue between the scientific community and society;

(d) establishing suitable means to address the ethics of science and of the use of scientific knowledge and its applications, specifically through establishing, promoting and supporting independent, multidisciplinary and pluralist ethics committees in order to assess the relevant ethical, legal, scientific and social issues related to research projects involving human beings, to provide ethical advice on ethical questions in research and development, to assess scientific and technological developments and to foster debate, education and public awareness and engagement of ethics related to research and development;

(e) promoting research and development that may address peace-building, as well as responsible and peaceful application of science and technology;

(f) giving recognition to the key role of research and development in the acquisition of knowledge, in addressing the root causes and impacts of conflict, and in achieving sustainable development; and

(g) using scientific and technological knowledge in decision-making and policies.

6. Member States should treat public funding of research and development as a form of public investment the returns on which are, for the most part, necessarily long-term, and take all appropriate measures to ensure that the justification for, and indeed the indispensability of such investment is held constantly before public opinion.

7. Member States should use scientific and technological knowledge in decision-making and policies for international relations, for which they should strengthen capacities for science diplomacy.

8. Member States should cultivate opportunities for scientific researchers to participate in developing national science, technology and innovation policy. In particular, each Member State should ensure that these policy processes are supported by appropriate institutional mechanisms enjoying adequate advice and assistance from scientific researchers and their professional organizations.

9. Member States should create the environment to ensure that scientific researchers, who give policy advice to policy-makers and other public officials, can do so in an accountable manner in which conflicts of interest are disclosed.

10. Each Member State should institute procedures adapted to its needs for ensuring that, in the performance of research and development, scientific researchers respect public accountability while at the same time enjoying the degree of autonomy appropriate to their task and to the advancement of science and technology. It should be fully taken into account that creativity of scientific researchers should be promoted in national policy on the basis of utmost respect for the autonomy and freedom of research indispensable to scientific progress.

11. With the above ends in view, and with respect for the principle of freedom of movement of scientific researchers, Member States should be concerned to create that general climate, and to provide those specific measures for the moral and material support and encouragement of scientific researchers, as will:

(a) ensure that people of high calibre find sufficient attraction in the vocation, and sufficient confidence in research and development as a career offering reasonable prospects and a fair degree of security, to maintain a constantly adequate regeneration of the nation's pool of scientific researchers;

(b) facilitate the emergence and stimulate the appropriate growth, among its own citizens, of a body of scientific researchers regarding themselves and regarded by their colleagues throughout the world as worthy members of the international scientific and technological community;

(c) encourage those scientific researchers (or young people who aspire to become scientific researchers) who seek some of their education, training or experience abroad, to return and to work in their country.

III. The initial education and training of scientific researchers

12. Member States should have regard for the fact that effective scientific research calls for scientific researchers of integrity and intellectual maturity, combining high, intellectual qualities and respect for ethical principles.

13. To assist the emergence of scientific researchers of this high calibre, Member States should take measures to:

(a) ensure that, without discrimination on the basis of race, colour, descent, sex, gender, sexual orientation, age, native language, religion, political or other opinion, national origin, ethnic origin, social origin, economic or social condition of birth, or disability, all citizens enjoy equal

opportunities for the initial education and training needed to qualify for research and development careers, as well as ensuring that all citizens who succeed in so qualifying enjoy equal access to available employment in scientific research;

(b) abolish inequalities of opportunities;

(c) in order to remediate past inequalities and patterns of exclusion, actively encourage women and persons of other under-represented groups to consider careers in sciences, and endeavour to eliminate biases against women and persons of other under-represented groups in work environments and appraisal;

(d) encourage the spirit of service both to the advancement of science and to social and ecological responsibilities toward their fellow nationals, humanity in general, future generations, and the earth including all its ecosystems, its sustainable development and its conservation, as an important element in their education and training;

(e) ensure equitable and open access to scientific literature, data and contents including by removing barriers to publishing, sharing and archiving of scientific outputs.

14. So far as is compatible with the necessary and proper independence of educators and educational institutions, Member States should lend their support to all educational initiatives designed to:

(a) strengthen all sciences, technology, engineering and mathematics education, in schools and other formal and informal settings;

(b) incorporate inter-disciplinary and art and design elements in curricula and courses of all sciences as well as skills such as communication, leadership and management;

(c) incorporate or develop in each domain's curricula and courses the ethical dimensions of science and of research;

(d) develop and use educational techniques for awakening and stimulating such personal qualities and habits of mind as:

(i) the scientific method;

(ii) intellectual integrity, sensitivity to conflict of interest, respect for ethical principles pertaining to research;

(iii) the ability to review a problem or situation in perspective and in proportion, with all its human implications;

(iv) skill in isolating the civic and ethical implications, in issues involving the search for new knowledge and which may at first sight seem to be of a technical nature only;

(v) vigilance as to the probable and possible social and ecological consequences of research and development activities;

(vi) willingness to communicate with others not only in scientific and technological circles but also outside those circles, which implies willingness to work in a team and in a multi-occupational context.

IV. Rights and responsibilities in research

15. Member States should bear in mind that the scientific researchers' sense of vocation can be powerfully reinforced if they are encouraged to think of their work in terms of service both to their fellow nationals and to their fellow human beings in general. Member States should seek, in their treatment of and attitude towards scientific researchers, to express encouragement for this broad spirit of responsibility.

The civic and ethical aspect of scientific research

16. Member States should encourage conditions that can deliver high-quality science in a responsible manner in line with paragraph 4 of this Recommendation. For this purpose, Member States should establish mechanisms and take all appropriate measures aimed to ensure the fullest exercise, respect, protection and promotion of the rights and responsibilities of scientific researchers and others concerned by this Recommendation. For this purpose:

(a) the following are the recommended responsibilities and rights of scientific researchers:

(i) to work in a spirit of intellectual freedom to pursue, expound and defend the scientific truth as they see it, an intellectual freedom which should include protection from undue influences on their independent judgement;

(ii) to contribute to the definition of the aims and objectives of the programmes in which they are engaged and to the determination of the methods to be adopted which should be humanely, scientifically, socially and ecologically responsible; in particular, researchers should seek to minimize impacts on living subjects of research and on the natural environment and should be aware of the need to manage resources efficiently and sustainably;

(iii) to express themselves freely and openly on the ethical, human, scientific, social or ecological value of certain projects, and in those instances where the development of science and technology undermine human welfare, dignity and human rights or is "dual

use", they have the right to withdraw from those projects if their conscience so dictates and the right and responsibility to express themselves freely on and to report these concerns;

(iv) to contribute constructively to the fabric of science, culture and education, and the promotion of science and innovation in their own country, as well as to the achievement of national goals, the enhancement of their fellow citizens' well-being, the protection of the environment, and the furtherance of the international ideals and objectives;

(v) to promote access to research results and engage in the sharing of scientific data between researchers, and to policy-makers, and to the public wherever possible, while being mindful of existing rights;

(vi) to disclose both perceived and actual conflicts of interest according to a recognized code of ethics that promotes the objectives of scientific research and development;

(vii) to integrate in their research and development work in an ongoing manner: disclosures to each human research subjects so as to inform their consent, controls to minimize harm to each living subject of research and to the environment, and consultations with communities where the conduct of research may affect community members;

(viii) to ensure that knowledge derived from sources, including traditional, indigenous, local, and other knowledge sources, is appropriately credited, acknowledged, and compensated as well as to ensure that the resulting knowledge is transferred back to those sources.

(b) the following are the recommended responsibilities and rights of persons or institutions that employ, fund, govern, or guide researchers and/or research:

(i) to bear and enjoy equivalent responsibilities and rights as above in (a), provided these rights and responsibilities do not impede on the scientific researchers' exercise of responsibilities and rights;

(ii) to facilitate the exercise of responsibilities and rights described in (a) and (b)(i), including by establishing mechanisms for this purpose, such as ethics review boards, and to ensure scientific researchers' protection from retribution;

(iii) to fully respect the intellectual property rights of individual researchers;

(iv) to follow this Recommendation in other respects; and

(v) to specify as explicitly and narrowly as possible the cases in which they deem it

necessary to depart from the recommended responsibilities and rights set out in paragraphs (a) and (b).

17. Member States should take all appropriate steps to urge all other employers of scientific researchers to follow the recommendations in paragraph 16 above.

The international aspect of scientific research

18. Member States should recognize the international dimensions of research and development and, in this regard, should do everything possible to help scientific researchers, including:

(a) establishing partnerships freely associating scientific communities of developed and developing countries to meet the needs of all countries and facilitate their progress while respecting national regulation, including cultural and scientific cooperation and development of bilateral and multilateral agreements enabling developing countries to build up their capacity to participate in generating and sharing scientific knowledge, the related know-how and their benefits, including identifying and countering the effects of brain drain;

(b) ensuring equal access to science and the knowledge derived from it as not only a social and ethical requirement for human development, but also as essential for realizing the full potential of scientific communities worldwide;

(c) put in place policies aiming to facilitate that the scientific researchers freely develop and contribute to sharing data and educational resources, for example by means of virtual universities;

(d) in the context of their intellectual property regime, ensuring that contributions to scientific knowledge are appropriately credited, and balancing between protection of intellectual property rights and the open access and sharing of knowledge, as well as ensuring the protection of sources and products of traditional knowledge;

(e) taking measures against biopiracy; illicit trafficking of organs, tissues, samples, genetic resources and genetic- related materials; as well as ensuring the protection of the human rights, fundamental freedoms and dignity of the human person, and the confidentiality of personal data.

19. Considering that any scientific research could improve the understanding of factors involved in the survival and well-being of humankind as a whole, Member States should provide support to these initiatives of scientific researchers, with due regard to:

(a) the impact of science on future generations;

(b) the interconnection between various forms of life;

(c) the role and responsibility of human beings in the protection of the environment, the biosphere and biodiversity.

20. Member States should endeavour to ensure that research and development undertaken, funded, or otherwise pursued in whole or in part in different States, is consistent with principles of conducting research in a responsible manner that respects human rights. In particular, for transnational research involving human subjects:

(a) appropriate ethical review should be undertaken both in the host State(s) and the State(s) in which the funder is located, based on internationally agreed ethical frameworks;

(b) such research should be responsive to the needs of host countries, and the importance of it contributing to the alleviation of urgent global health problems should be recognized;

(c) when negotiating a research agreement and terms for collaboration, agreement on the benefits of the research and access to the results should be established with full participation of the communities concerned.

21. So as to ensure the human right to share in scientific advancement and its benefits, Member States should establish and facilitate mechanisms for collaborative open science and facilitate sharing of scientific knowledge while ensuring other rights are respected.

22. So as to ensure the human right to health, Member States should take measures so that benefits resulting from any research and its applications are shared with society as a whole and within the international community, in particular with developing countries.

23. In order that the scientific and technological knowledge and its potentialities be promptly geared to the benefit of all peoples, Member States should urge scientific researchers, and other actors to whom this Recommendation applies, to keep in mind the principles set out in paragraphs 18, 19, 20, 21 and 22 above.

V. Conditions for success on the part of scientific researchers

24. Member States should:

(a) provide material assistance, moral support and public recognition conducive to successful performance in research and development by scientific researchers;

(b) ensure that scientific researchers enjoy equitable conditions of work, recruitment and promotion, appraisal, training and pay without discrimination on the basis of race, colour, descent, sex, gender, sexual orientation, age, native language, religion, political or other opinion, national origin, ethnic origin, social origin, economic or social condition of birth, or

disability;

(c) support individuals from underrepresented groups entering and developing careers in research and development.

25. Member States should develop policies for the protection and preservation of research objects, scientific infrastructure and scientific archives, including in instances of conflict.

26. Member States should establish as a norm for any scientific publishing, including publishing in open access journals, that peer review based on established quality standards for science is essential.

Adequate career development prospects and facilities

27. Member States should develop policies with respect to employment that adequately cover the needs of scientific researchers, in particular by:

(a) providing scientific researchers in their direct employment with adequate career development prospects and facilities, including but not limited to research and development;

(b) making every effort so that scientific researchers are not subjected, merely by the nature of their work, to avoidable hardship;

(c) providing the necessary funds and mechanisms for training opportunities, career development, and/or redeployment, in respect of the scientific researchers in their permanent employ, in order to address precariousness due to mobility or limited-duration contracts;

(d) offering challenging opportunities for early career scientific researchers to do significant research and development, in accordance with their abilities, and to rapidly undertake a stable career – though not necessarily exclusively in the fields of research and development;

(e) recognizing that various fields of scientific research and development require different levels of skills and durations of training;

(f) promoting and supporting open scholarship by scientific researchers, as well as promoting open access to literature and research data, as essential parts of research.

Lifelong learning

28. Member States should encourage the provision of facilities so that scientific researchers enjoy lifelong opportunities for keeping themselves up to date in their own and in other scientific fields, by attendance at conferences, by free access to international databases and journals, libraries and other sources of information, and by participation in training.

Mobility

29. Member States should enable and facilitate mobility of scientific researchers between public sector, private sector and higher education employment, as well as outside of research and development.

30. With regard to mobility of scientific researchers between research and development and other public functions, Member States should:

(a) provide procedures for the periodic review of the material conditions of scientific researchers to ensure that they remain equitably comparable with those of other workers having equivalent experience and qualifications and in keeping with the country's standard of living;

(b) introduce conditions of employment specially designed for scientific researchers benefitting from this mobility; and

(c) provide the scientific researchers benefitting from this mobility with adequate career development prospects.

Participation in the international scientific and technological community

31. In line with paragraph 16 of this Recommendation, Member States should actively promote the interplay of ideas and information among scientific researchers throughout the world, which is vital to the healthy development of the sciences; and to this end, should take all measures necessary to ensure that scientific researchers are enabled, throughout their careers, to participate in the international scientific and technological community. Member States should facilitate this travel in and out of their territory.

Protection of health; social security

32. Member States should guarantee that, for the health and safety of scientific researchers as of all other persons likely to be affected by the research and development activity in question, all national regulations, and the international instruments concerned with the protection of workers in general from hostile or dangerous environments will be fully met. They should accordingly ensure that the managements of scientific establishments: enforce appropriate safety standards; train all those in their employ in the necessary safety procedures; monitor and safeguard the health of all persons at risk; take due note of warnings of new (or possible new) hazards brought to their attention, in particular by the scientific researchers themselves, and act accordingly; and ensure that the working day and rest periods are of reasonable length, the latter to include annual and parental leave on full pay.

33. Member States should ensure that provision is made for scientific researchers to enjoy (in common with all other workers) adequate and equitable social security arrangements appropriate to their age, sex, family situation, state of health and to the nature of the work they perform.

Performance appraisal

34. Member States should, as regards scientific researchers in their employ, design and establish appropriate (using international comparisons so as to adopt good practices) appraisal systems for independent, transparent, gender-sensitive and tier-based performance evaluation that:

(a) take due account of all aspects of the work including, inter alia, contributions to publications, patents, management, teaching, outreach, supervision, collaboration, ethics compliance, and science communications;

(b) take due account of the difficulty inherent in measuring a performance given the effects of mobility between themes and disciplines, the blurring of boundaries between disciplines, the appearance of new disciplines and the need to appraise all aspects of the individual's performance in context;

(c) combine appropriate metrics with independent expert assessment (peer review) of the individual's outputs, as to all aspects of the work including those aspects mentioned above in (a);

(d) transparently account for family-care related interruptions of employment and encourage equitable treatment by means of incentives, so that the careers and research of those who take family related leave, including parental leave, are not negatively impacted as a result;

(e) encourage, by means of incentives, sharing of the whole scientific process (data, methods, software, results, etc.) and mentoring early career people in the sciences.

Expression by publication

35. Member States should encourage and facilitate publication of the results obtained by scientific researchers, and extend this to the data, methods, software, that they used, with a view to assisting them to share scientific information, and to acquire the reputation that they merit, as well as with a view to promoting the sciences, education and culture generally.

36. In order to promote science as a public good, Member States should encourage and facilitate access to knowledge, including open access.

37. Member States should ensure that the scientific and technological results of scientific researchers enjoy appropriate legal protection of their intellectual property, and in particular the protection afforded by patent and copyright law.

38. In those cases where restrictions are placed upon scientific researchers' right to publish or communicate results, Member States should ensure:

(a) that such restrictions are: strictly minimized, consistent with public interest and the right of their employers and fellow workers, consistent with appropriately crediting and acknowledged contributions of scientific researchers to the results obtained, and properly communicated as clearly as possible in writing in the terms and conditions of their employment;

(b) that the procedures by which scientific researchers can ascertain whether the restrictions mentioned in this paragraph apply in a particular case and by which mechanism they can appeal are made clear.

Recognition

39. Member States should ensure that scientific researchers may:

(a) receive without hindrance the questions, criticisms and suggestions addressed to them by their colleagues throughout the world, as well as the intellectual stimulus afforded by such communications and the exchanges to which they give rise;

(b) enjoy in tranquillity international acclaim warranted by their scientific merit.

40. Similarly, Member States should adopt the following standard practices:

(a) written provisions to be included in the terms and conditions of employment of scientific researchers, stating clearly what rights (as applicable) belong to them (and, where appropriate, to other interested parties) in respect of their contributions to any discovery, invention, or improvement in technical knowhow or commercialization which may arise in the course of or as a result of the research and development that those scientific researchers undertake;

(b) the attention of scientific researchers to be always drawn by the employer to such written provisions before the scientific researchers enter employment.

Reasonable flexibility in the interpretation and application of texts setting out the terms and conditions of employment of scientific researchers

41. Member States should seek to ensure that the performance of research and development be not reduced to pure routine. They should therefore see to it that all texts setting out terms of employment for, or governing the conditions of work of scientific researchers, be framed and

interpreted with all the necessary flexibility to meet the requirements of research and development. This flexibility should not however be invoked in order to impose on scientific researchers conditions that are inferior to those enjoyed by other workers of equivalent qualifications and responsibility.

The advancement of their various interests by scientific researchers in association

42. Member States should recognize it as wholly legitimate, and indeed desirable, that scientific researchers should associate to protect and promote their individual and collective interests, in bodies such as trade unions, professional associations and learned societies, in accordance with the rights of workers in general and inspired by the principles set out in the international instruments listed in the annex to this Recommendation. In all cases where it is necessary to protect the rights of scientific researchers, these organizations should have the right to support the justified claims of such researchers.

43. Member States should recognize that they have, as employers of scientific researchers, a leading responsibility and should attempt to set an example to other employers of scientific researchers, and, in order to ensure that satisfactory working conditions are available to scientific researchers in all settings in which research and development are conducted, Member States should take measures to urge all employers of scientific researchers to adopt and use mechanisms, policies and practices reflecting the principles set out in paragraphs 24, 27, 28, 29, 31, 32, 34, 35, 36, 37, 38, 39, 40, 41 and 42 above.

VI. Utilization and exploitation of the present Recommendation

44. Member States should strive to extend and complement their own action in respect of this Recommendation, by cooperating with all national and international organizations whose activities fall within the scope and objectives of this Recommendation, in particular: National Commissions for UNESCO; international organizations; organizations representing science and technology educators; employers generally; learned societies, professional associations and trade unions of scientific researchers; associations of science writers; women in science associations; youth and student organizations.

45. Member States should support the work of the bodies mentioned above by the most appropriate means, including relevant policies.

46. Member States should periodically review the conditions of scientific researchers, disaggregating data as much as possible in particular by sex.

47. Member States should enlist the vigilant and active cooperation of all organizations representing scientific researchers, in ensuring that the latter may, in a spirit of community service, effectively assume the responsibilities, enjoy the rights and obtain the recognition of the status described in this Recommendation.

VII. Final provision

48. Where scientific researchers enjoy a status that is, in certain respects, more favourable than the minimum norm outlined throughout this Recommendation, the terms of this Recommendation should not be invoked to diminish the status already acquired.

References

500 Women Scientists. (2020). Scientist mothers face extra challenges in the face of COVID-19. *Scientific American*. https://blogs.scientificamerican.com/voices/scientist-mothers-face-extra-challenges-in-the-face-of-covid-19/.

Allen, A. (2020). For billion-dollar COVID vaccines, basic government-funded science laid the groundwork. *Scientific American*. https://www.scientificamerican.com/article/for-billion-dollar-covid-vaccines-basic-government-funded-science-laid-the-groundwork/.

Almassi, B. (2012). Climate change, epistemic trust, and expert trustworthiness. *Ethics and the Environment 17*(2), 29-49. https://doi.org/10.2979/ethicsenviro.17.2.29.

American Association for the Advancement of Science. (2010). A*AAS statement on scientific freedom & responsibility*. https://www.aaas.org/programs/scientific-responsibility-human-rights-law/aaas-statement-scientific-freedom.

American College of Epidemiology. (2000). *Ethics guidelines*. https://www.acepidemiology.org/ethics-guidelines.

American Educational Research Association. (n.d.) *Selected findings on LGBTQ student achievement and educational attainment.* https://www.aera.net/LinkClick.aspx?fileticket=CMZhjWRaPBw%3d&tabid=16010&portalid=38&mid=39464.

American Educational Research Association. (n.d). *Selected LGBT research recommendations*. https://www.aera.net/LinkClick.aspx?fileticket=h7jfRILqcnE%3d&tabid=16010&portalid=38&mid=39464.

Andrews, A. M., Cheng, X., Altieri, S. C., & Yang, H. (2018). Bad behavior: Improving reproducibility in behavior testing. *ACS Chemical Neuroscience*, *9*(8), 1904–1906. https://doi.org/10.1021/acschemneuro.7b00504.

Artino, A. R. Jr., Driessen, E. W., & Maggio, L. A. (2019). Ethical shades of gray: International frequency of scientific misconduct and questionable research practices in health professions education. *Academic Medicine*, *94*(1), 76–84. https://doi.org/10.1097/ACM.0000000000002412.

Aschwanden, C. (2016, January 6). *You can't trust what you read about nutrition.* FiveThirtyEight. https://fivethirtyeight.com/features/you-cant-trust-what-you-read-about-nutrition/.

Australian Government. (2007). *Australian code for the Responsible Conduct of Research*. https://www.nhmrc.gov.au/sites/default/files/documents/reports/australian-code-responsible-conduct-research.pdf.

Baier, A. (1986). Trust and antitrust. *Ethics*, *96*(2), 231–60. https://doi.org/10.1086/292745.

Begley, C. G., Buchan, A. M., & Dirnagl, U. (2015). Robust research: Institutions must do their part for reproducibility. *Nature*, 525, 25–27. https://doi.org/10.1038/525025a.

Begley, C. G., & Ellis, L. M. (2012). Raise standards for preclinical cancer research. *Nature*, *483,* 531–533. https://doi.org/10.1038/483531a.

Bennett, J. C., Lattuca, L., Redd, K., & York, T. (2020). *Strengthening pathways to faculty careers in STEM: Recommendations for systemic change to support underrepresented groups*.

Association of Public and Land-grant Universities.
https://www.aplu.org/library/strengthening-pathways-to-faculty-careers-in-stem-recommendations-for-systemic-change-to-support-underrepresented-groups/file.

Berman, E. and Carter, J. (2018). Policy analysis: Scientific integrity in federal policymaking under past and present administrations. *Journal of Science Policy & Governance*, *13*(1). https://www.sciencepolicyjournal.org/uploads/5/4/3/4/5434385/berman_emily__carter_jacob.pdf.

Bernstein, R. (2015). Depression afflicts almost half of STEM graduate students at UC Berkeley. *Science*. https://www.sciencemag.org/careers/2015/05/depression-afflicts-almost-half-stem-graduate-students-uc-berkeley.

Bonney, R., Phillips, T. B., Ballard, H. L., & Enck, J. W. (2016). Can citizen science enhance public understanding of science? *Public Understanding of Science, 25*(1), 2–16. https://doi.org/10.1177/0963662515607406

Brainard, J., & You, J. (2018). What a massive database of retracted papers reveals about science publishing's "death penalty." *Science*. https://www.sciencemag.org/news/2018/10/what-massive-database-retracted-papers-reveals-about-science-publishing-s-death-penalty.

Brown, J. R. (2002). Funding, objectivity and the socialization of medical research. *Science and Engineering Ethics*, *8*(3), 295–308.

Burris, C. C., Welner, K. G., & Bezoza, J. W. (2009). *Universal access to a quality education: research and recommendations for the elimination of curricular stratification*. National Education Policy Center. https://nepc.colorado.edu/publication/universal-access.

Cardel, M. I., Dean, N., & Montoya-Williams, D. (2020). Preventing a secondary epidemic of lost early career scientists. Effects of COVID-19 pandemic on women with children. *Annals of the American Thoracic Society, 17*(11). https://doi.org/10.1513/AnnalsATS.202006-589IP.

Carroll, C., Hartl, B., Goldman, G. T., Rohlf, D. J., Treves, A., Kerr, J. T., Ritchie, E. G., Kingsford, R. T., Gibbs, K. E., Maron, M., & Watson, J. (2017). Defending the scientific integrity of conservation-policy processes. *Conservation Biology: The Journal of the Society for Conservation Biology*, *31*(5), 967–975. https://doi.org/10.1111/cobi.12958.

Carter, J. M., Goldman, G. T., Rosenberg, A. A., Reed, G., Desikan, A., MacKinney, T. (2021). Strengthen scientific integrity under the Biden administration. *Science, 371*(6530), 668-671. https://doi.org/10.1126/science.abg0533.

Cech, E. A.., & Pham, M. V. (2017). Queer in STEM organizations: Workplace disadvantages for LGBT employees in STEM related federal agencies. *Social Sciences, 6*(1), 12. https://doi.org/10.3390/socsci6010012.

Centers for Disease Control and Prevention. (n.d.) *Disability impacts all of us*. https://www.cdc.gov/ncbddd/disabilityandhealth/infographic-disability-impacts-all.html.

Chambers, C. D., Feredoes, E., Muthukumaraswamy, S. D., & Etchells, P. J. (2014). Instead of "playing the game" it is time to change the rules: Registered reports at *AIMS Neuroscience* and beyond. *AIMS Neuroscience*, *1*(1), 4-17. https://doi.org/10.3934/Neuroscience.2014.1.4.

Chambers, K., Collings, A., Graf, C., Kiermer, V., Mellor, D. T., Macleod, M., Swaminathan, S., Sweet, D., & Vinson, V. (2019). Towards minimum reporting standards for life scientists. https://doi.org/10.31222/osf.io/9sm4x.

Chen, M. S., Jr, Lara, P. N., Dang, J. H., Paterniti, D. A., & Kelly, K. (2014). Twenty years post-NIH Revitalization Act: enhancing minority participation in clinical trials (EMPaCT): laying the groundwork for improving minority clinical trial accrual: renewing the case for enhancing minority participation in cancer clinical trials. *Cancer*, *120 Suppl 7*, 1091–1096. https://doi.org/10.1002/cncr.28575.

CitSci.org.(n.d.) https://www.citsci.org/CWIS438/Websites/CitSci/Home.php?WebSiteID=7.

Congressional Research Service (2020). F*ederal scientific integrity policies: A primer*. https://crsreports.congress.gov/product/pdf/R/R46614.

Corbett, C., & Hill, C. (2015). *Solving the equation: The variables for women's success in engineering & computing.* American Association of University Women. https://www.aauw.org/app/uploads/2020/03/Solving-the-Equation-report-nsa.pdf.

Corley, E. A., Kim, Y., & Scheufele, D. A. (2016). Scientists' ethical obligations and social responsibility for nanotechnology research. S*cience and Engineering Ethics 22,* 111–132. https://doi.org/10.1007/s11948-015-9637-1.

Cross, R. (2021). Will public trust in science survive the pandemic? *Chemical and Engineering News*, *99*(3). https://cen.acs.org/policy/global-health/Will-public-trust-in-science-survive-the-pandemic/99/i3.

DeVito, N. J., & Goldacre, B. (2019). Catalogue of bias: publication bias. *BMJ Evidence-Based Medicine*, *24*, 53-54. http://dx.doi.org/10.1136/bmjebm-2018-111107.

DeWitt, P., Schneiderwind, J., & Johnson, J. (2020). Why are students with disabilities so invisible in STEM education? *EducationWeek*. https://www.edweek.org/education/opinion-why-are-students-with-disabilities-so-invisible-in-stem-education/2020/07.

DiDomenico, R. J., Baker, W. L., & Haines, S. T. (2017). Improving peer review: What reviewers can do. *American Journal of Health-System Pharmacy*, *74*(24), 2080–2084. https://doi.org/10.2146/ajhp170190.

Douglas, H. (2014). The moral terrain of science. *Erkenntnis*, *79*(5), 961–979. https://doi.org/10.1007/s10670-013-9538-0.

Dunn, C., Rabren, K. S., Taylor, S. L., & Dotson, C. K. (2012). Assisting students with high-incidence disabilities to pursue careers in science, technology, engineering, and mathematics. *Intervention in School and Clinic*, *48*(1), 47–54. https://doi.org/10.1177/1053451212443151.

Education Commission of the States. (n.d.) *Vital Signs*. https://vitalsigns.ecs.org/.

Education Commission of the States. (2016). *Bridging the computer science access gap (infographics) (August 2016)*. http://ecs.force.com/studies/rstempg?id=a0r0g000009TLeI.

Electronic Code of Federal Regulations (2017). *Basic HHS policy for protection of human research subjects ["The Common Rule"]*. https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=83cd09e1c0f5c6937cd9d7513160fc3f&pitd=20180719&n=pt45.1.46&r=PART&ty=HTML.

Erickson, L. 2020. *The disproportionate impact of COVID-19 on women of color*. Society for Women's Health Research. https://swhr.org/the-disproportionate-impact-of-covid-19-on-women-of-color/.

Falk, J. H, & Dierking, L. D. (2010). The 95 percent solution. *American Scientist, 98*(6), 486. https://doi.org/10.1511/2010.87.486.

Fanelli, D. (2009). How many scientists fabricate and falsify research? A systematic review and meta-analysis of survey data. *PLoS ONE 4*(5), e5738. https://doi.org/10.1371/journal.pone.0005738.

Fanelli, D., Costas, R., & Larivière, V. (2015). Misconduct policies, academic culture and career stage, not gender or pressures to publish, affect scientific integrity. *PLoS ONE*, *10*(6), e0127556. https://doi.org/10.1371/journal.pone.0127556.

Fang, F. C., Steen, R. G., & Casadevall, A. (2012). Misconduct accounts for the majority of retracted scientific publications. *Proceedings of the National Academy of Sciences of the United States of America*, *109*(42), 17028–17033. https://doi.org/10.1073/pnas.1212247109.

Fisher, D. R. (2018). Scientists in the resistance. *Sociological Forum*, *33*(1), 247–250. https://doi.org/10.1111/socf.12396.

Freedman, L. P., Cockburn, I. M., & Simcoe, T. S. (2015). The economics of reproducibility in preclinical research. *PLoS Biology*, *13*(6), e1002165. https://doi.org/10.1371/journal.pbio.1002165.

Freeman, J. (2019). How to fight STEM's unconscious bias against LGBTQ people. S*cientific American*. https://blogs.scientificamerican.com/voices/how-to-fight-stems-unconscious-bias-against-lgbtq-people/.

Funk, C. (2020, February 12). *Key findings about Americans' confidence in science and their views on scientists' role in society.* Pew Research Center. https://www.pewresearch.org/fact-tank/2020/02/12/key-findings-about-americans-confidence-in-science-and-their-views-on-scientists-role-in-society/.

Funk, C., Hefferon, M., Kennedy, M., & Johnson, C. (2019a, August 2). *Partisanship influences views on the role and value of scientific experts in policy debates*. Pew Research Center. https://www.pewresearch.org/science/2019/08/02/partisanship-influences-views-on-the-role-and-value-of-scientific-experts-in-policy-debates/#more-democrats-than-republicans-trust-the-objectivity-of-scientists-and-the-scientific-method.

Funk, C., Hefferon, M., Kennedy, M., & Johnson, C. (2019b, August 2). *Americans often trust practitioners more than researchers but are skeptical about scientific integrity*. Pew Research Center. https://www.pewresearch.org/science/2019/08/02/americans-often-trust-practitioners-more-than-researchers-but-are-skeptical-about-scientific-integrity/.

Funk, C., & Hefferon, M. (2019c, November 25). *U.S. public views on climate and energy*. Pew Research Center. https://www.pewresearch.org/science/2019/11/25/u-s-public-views-on-climate-and-energy/.

Funk, C., & Parker, K. (2018, January 9). *Women and men in STEM often at odds over workplace equity*. Pew Research Center. https://www.pewsocialtrends.org/2018/01/09/women-and-men-in-stem-often-at-odds-over-workplace-equity/.

GO FAIR. (n.d.). *FAIR principles*. https://www.go-fair.org/fair-principles/.

Goldenberg, M. J. (2016). Public misunderstanding of science? Reframing the problem of vaccine hesitancy. *Perspectives on Science 24*(5), 552-581. https://doi.org/10.1162/POSC_a_00223.

Goldenberg, M. J. (2021). *Vaccine hesitancy: Public trust, expertise, and the war on science*. University of Pittsburgh Press.

Goldman, G., Berman, E., Halpern, M., Johnson, C., Kothari, Y., Reed, G., & Rosenberg, A. A. (2017). Ensuring scientific integrity in the age of Trump. *Science 355*(6326), 696-698. https://doi.org/10.1126/science.aam5733.

Goldman, G. T., Carter, J. M., Wang, Y., & Larson, J. M. (2020). Perceived losses of scientific integrity under the Trump administration: A survey of federal scientists. *PLoS ONE.* https://doi.org/10.1371/journal.pone.0231929.

Goodman, S. N., Fanelli, D., & Ioannidis, J. P. (2016). What does research reproducibility mean? *Science Translational Medicine*, *8*(341), 341ps12. https://doi.org/10.1126/scitranslmed.aaf5027.

Gottfried, J., & Funk, C. (2017, September 21). *Most Americans get their science news from general outlets, but many doubt their accuracy*. Pew Research Center. https://www.pewresearch.org/fact-tank/2017/09/21/most-americans-get-their-science-news-from-general-outlets-but-many-doubt-their-accuracy/.

Gottlieb, J. D., & Bressler, N. M. (2017). How should journals handle the conflict of interest of their editors? Who watches the "watchers"? *JAMA, 317*(17), 1757–1758. https://doi.org/10.1001/jama.2017.2207.

Government Accountability Office. (2016). *K-12 education: Better use of information could help agencies identify disparities and address racial discrimination*. https://www.gao.gov/assets/680/676745.pdf.

Government Accountability Office. (2019, April 4). *Scientific integrity policies: Additional actions could strengthen integrity of federal research*. https://www.gao.gov/products/gao-19-265.

Grasswick, H. (2010). Scientific and lay communities: earning epistemic trust through knowledge sharing. *Synthese*, *177,* 387–409. https://doi.org/10.1007/s11229-010-9789-0.

Guterl, F. (2014, October 1). *Diversity in science: Where are the data?* Scientific American. https://www.scientificamerican.com/article/diversity-in-science-where-are-the-data/.

Haffar, S., Bazerbachi, F., & Murad, M. H. (2019). Peer review bias: A critical review. *Mayo Clinic Proceedings, 94*(4), 670-676. https://doi.org/10.1016/j.mayocp.2018.09.004.

Handelsman, J., & Ward, W. E. (2016, December 12). *Increasing diversity in the STEM workforce by reducing the impact of bias.* The White House. https://obamawhitehouse.archives.gov/blog/2016/12/12/increasing-diversity-stem-workforce-reducing-impact-bias.

Hansen, T. (2018, September 20). Breaking a sacred trust: On the exploitation of traditional Native knowledge. *Pacific Standard*. https://psmag.com/social-justice/breaking-a-sacred-trust.

Herold, B. (2020). The disparities in remote learning under coronavirus (in charts). *EducationWeek*. https://www.edweek.org/technology/the-disparities-in-remote-learning-under-coronavirus-in-charts/2020/04.

Hill, C., Corbett, C., & St. Rose, A. (2010). W*hy so few? Women in science, technology, engineering, and mathematics*. American Association of University Women. https://www.aauw.org/app/uploads/2020/03/why-so-few-research.pdf.

Hippel, F. V., & Primack, J. (1972). Public interest science. *Science*, *177*(4055), 1166–71. https://science.sciencemag.org/content/177/4055/1166.

Hotez, P. J., & Jackson Lee, S. (2017). U.S. Gulf Coast states: The rise of neglected tropical diseases in "flyover nation"*. PLoS Neglected Tropical Diseases*, *11*(11). https://doi.org/10.1371/journal.pntd.0005744.

Huamani, K. F., Metch, B., Broder, G., & Andrasik, M. (2019). A demographic analysis of racial/ethnic minority enrollment Into HVTN preventive early phase HIV vaccine clinical trials conducted in the United States, 2002-2016. *Public health reports 134*(1), 72–80. https://doi.org/10.1177/0033354918814260.

Hughes, B. E. (2018). Coming out in STEM: Factors affecting retention of sexual minority STEM students. *Science Advances, 4*(3). https://doi.org/10.1126/sciadv.aao6373.

John, L. K., Loewenstein, G., Marder, A., & Callaham, M. L. (2019). Effect of revealing authors' conflicts of interests in peer review: randomized controlled trial. *BMJ*, *367*, l5896. https://doi.org/10.1136/bmj.l5896.

Jones, K. (1996). Trust as an affective attitude. *Ethics*, *107*(1), 4–25. http://www.jstor.org/stable/2382241.

Kahan, D. (2015). Climate-science communication and the measurement problem. *Advances in Political Psychology*, *36*(1), 1-43. https://doi.org/10.1111/pops.12244.

Kalichman, M. (2014). Rescuing responsible conduct of research (RCR) education. *Accountability in research*, *21*(1), 68–83. https://doi.org/10.1080/08989621.2013.822271.

Kelly, M. L., Reed, G., Goldman, G. T., and Carter, J. M. Safeguarding against distortions of scientific research in federal policymaking. *The Environmental Law Reporter*, *51*(1). https://elr.info/news-analysis/51/10014/safeguarding-against-distortions-scientific-research-federal-policymaking.

Kennedy, B., and Hefferon, M. (2019, March 28). *What Americans know about science*. Pew Research Center. https://www.pewresearch.org/science/2019/03/28/what-americans-know-about-science/.

Koocher, G., & Keith-Spiegel, P. (2010). Peers nip misconduct in the bud. *Nature, 466*, 438–440. https://doi.org/10.1038/466438a.

Kourany, Janet A. (2010). *Philosophy of science after feminism*. Oxford University Press.

Krim, J. S., Coté, L. E., Schwartz, R. S., Stone, E. M., Cleeves, J. J., Barry, K. J., Burgess, W., Buxner, S. R., Gerton, J. M., Horvath, L., Keller, J. M., Lee, S. C., Locke, S. M., & Rebar, B. M. Models and impacts of science research experiences: A review of the literature of CUREs, UREs, and TREs. *CBE Life Sciences Education, 18*(4). https://doi.org/10.1187/cbe.19-03-0069.

Krimsky, S. (2003). *Science in the private interest: Has the lure of profits corrupted biomedical research?* Rowman & Littlefield Publishers.

Kurtz, L., and Goldman, G. (2020). 10 steps that can restore scientific integrity in government. *Scientific American*. https://www.scientificamerican.com/article/10-steps-that-can-restore-scientific-integrity-in-government/.

Landis, S. C., Amara, S. G., Asadullah, K., Austin, C. P., Blumenstein, R., Bradley, E. W., Crystal, R. G., Darnell, R. B., Ferrante, R. J., Fillit, H., Finkelstein, R., Fisher, M., Gendelman, H. E., Golub, R. M., Goudreau, J. L., Gross, R. A., Gubitz, A. K., Hesterlee, S. E., Howells, D. W., Huguenard, J., … Silberberg, S. D. (2012). A call for transparent reporting to optimize the predictive value of preclinical research. *Nature*, *490*(7419), 187–191. https://doi.org/10.1038/nature11556.

Langin, K. (2018). NSF moves to pilot LGBT questions on national workforce surveys. *Science*. https://www.sciencemag.org/careers/2018/11/nsf-moves-pilot-lgbt-questions-national-workforce-surveys.

Langin, K. (2020). As the pandemic erodes grad student mental health, academics sound the alarm. *Science*. https://www.sciencemag.org/careers/2020/09/pandemic-erodes-grad-student-mental-health-academics-sound-alarm.

Langin, K. (2021). Pandemic hit academic mothers especially hard, new data confirm. *Science*. https://www.sciencemag.org/careers/2021/02/pandemic-hit-academic-mothers-especially-hard-new-data-confirm.

Lathem, S. A., Neumann, M. D., & Hayden, N. (2013). The socially responsible engineer: Assessing student attitudes of roles and responsibilities. *Journal of Engineering Education*, *100*(3), 444-474. https://doi.org/10.1002/j.2168-9830.2011.tb00022.x.

Lee, A. (2014). Students with disabilities choosing science technology engineering and math (STEM) majors in postsecondary institutions. *Journal of Postsecondary Education and Disability*, *27*(3), 261-272. https://files.eric.ed.gov/fulltext/EJ1048786.pdf.

Lee, M-K, & Erdogan, I. (2007). The effect of science-technology-society teaching on students' attitudes toward science and certain aspects of creativity. *International Journal of Science Education*, *29*(11), 1315-1327. https://doi.org/10.1080/09500690600972974.

Leonelli, S. (2018). Rethinking reproducibility as a criterion for research quality. In M. Boumans & Chao, H-K, Eds., *Including a symposium on Mary Morgan: Curiosity, imagination, and surprise: Volume 36B* (pp. 129-146). Research in the History of Economic Thought and Methodology. Emerald Publishing. https://doi.org/10.1108/S0743-4154201836B.

MacKinney, T., Carter, J., Reed, G., Goldman, G., & Desikan, A. (2020, August 25). *A roadmap for science in decisionmaking.* Union of Concerned Scientists. https://www.ucsusa.org/resources/roadmap-science-decisionmaking.

MacPhee, D., Farro, S. & Canetto, S. S. (2013). Academic self-efficacy and performance of underrepresented STEM majors: Gender, ethnic, and social class patterns. *Analyses of Social Issues and Public Policy*, *13*(1), 347-369. https://doi.org/10.1111/asap.12033.

Malcom, S. M., Hall, P. Q., & Brown, J. W. (1976). *The double bind: The price of being a minority woman in science*. American Association for the Advancement of Science. https://www.aaas.org/news/1976/04/05/aaas-office-opportunities-science-double-bind-price-being-minority-woman-science.

Malcom, L. E., & Malcom, S. M. (2011). The double bind: The next generation. *The Harvard Educational Review, 81*(2). https://www.hepg.org/her-home/issues/harvard-educational-review-volume-81-number-2/herarticle/the-next-generation_815.

Malcom-Piqueux, L., & Malcom, S. (2020). *Workforce concerns - Work*place *concerns* [Infographic]. American Association for the Advancement of Science.

McGarity, T. O., & Wagner, W. (2008). *Bending science: How special interests corrupt public health research*. Harvard University Press.

Michalek, A. M., Hutson, A. D., Wicher, C. P., Trump, D. L. (2010). The costs and underappreciated consequences of research misconduct: A case study. *PLoS Medicine*, *7*(8), e1000318. https://doi.org/10.1371/journal.pmed.1000318.

Mitchell, F. 2020. *COVID-19's disproportionate effects on children of color will challenge the next generation*. The Urban Institute. https://www.urban.org/urban-wire/covid-19s-disproportionate-effects-children-color-will-challenge-next-generation.

Moore, K. (1993). *Doing good while doing science: The origins and consequences of public interest science organizations in America, 1945-1990.* [Doctoral dissertation, The University of Arizona]. University of Arizona Libraries.

Moore, K. (1996). Organizing integrity: American science and the creation of public interest science organizations, 1955–1975. *American Journal of Sociology*, *101*(6), 1592–1627. https://doi.org/10.1086/230868.

Myers, B. (2018, March 27). Women and minorities in tech, by the numbers. *Wired*. https://www.wired.com/story/computer-science-graduates-diversity/.

Mumba, F., & Chitiyo, M. (2008). High school science teachers' curriculum, instructional and assessment decisions for inclusive classes. *Problems of Education in the 21st Century*, *9*, 74–80. http://www.scientiasocialis.lt/pec/node/179.

National Academy of Engineering. (2009). *Ethics education and scientific and engineering research: What's been learned? What should be done? Summary of a workshop*. https://doi.org/10.17226/12695.

National Academies of Sciences, Engineering, and Medicine. (2016). *Barriers and opportunities for 2-year and 4-year STEM degrees: Systemic change to support students' diverse pathways*. https://doi.org/10.17226/21739.

National Academies of Sciences, Engineering, and Medicine. (2017). *Fostering integrity in research*. https://doi.org/10.17226/21896.

National Academies of Sciences, Engineering, and Medicine. (2018a). *Indicators for monitoring undergraduate STEM education*. https://doi.org/10.17226/24943.

National Academies of Sciences, Engineering, and Medicine. (2018b). *Sexual harassment of women: Climate, culture, and consequences in academic sciences, engineering, and medicine*. https://doi.org/10.17226/24994.

National Academies of Sciences, Engineering, and Medicine. (2019a). *Monitoring educational equity*. https://doi.org/10.17226/25389.

National Academies of Sciences, Engineering, and Medicine. (2019b). S*cience and engineering for grades 6-12: Investigation and design at the center*. https://doi.org/10.17226/25216.

National Academies of Sciences, Engineering, and Medicine. (2020a). *Enhancing scientific reproducibility in biomedical research through transparent reporting: Proceedings of a workshop*. https://doi.org/10.17226/25627.

National Academies of Sciences, Engineering, and Medicine. (2020b). *Understanding the well-being of LGBTQI+ populations*. https://doi.org/10.17226/25877.

National Audubon Society. (n.d.) *Audubon Christmas Bird Count*. https://www.audubon.org/conservation/science/christmas-bird-count.

National Center for Transgender Equality. (2021). *Issues: employment*. https://transequality.org/issues/employment.

National Institute of Food and Agriculture. (n.d.). *Responsible and ethical conduct of research*. United States Department of Agriculture. https://nifa.usda.gov/responsible-and-ethical-conduct-research.

National Institutes of Health. (2009, November 20). *Update on the requirement for instruction in the Responsible Conduct of Research*. https://grants.nih.gov/grants/guide/notice-files/not-od-10-019.html.

National Institutes of Health. (2014, March 18). *Public access policy: When and how to comply*. https://publicaccess.nih.gov/.

National Institutes of Health. (2017). *NIH policy and guidelines on the inclusion of women and minorities as subjects in clinical research*. https://grants.nih.gov/policy/inclusion/women-and-minorities/guidelines.htm.

National Institutes of Health. (2020, October 29). *Final NIH policy for data management and sharing*. https://grants.nih.gov/grants/guide/notice-files/NOT-OD-21-013.html.

National Research Council. (2009). *Learning science in informal environments: People, places, and pursuits*. https://doi.org/10.17226/12190.

National Research Council. (2013). *Monitoring progress toward successful K-12 STEM education: A nation advancing?* https://doi.org/10.17226/13509.

National Science Board, National Science Foundation. (2014). *Science and engineering indicators 2014*. https://www.nsf.gov/statistics/seind14/index.cfm/chapter-1/c1s2.htm.

National Science Board, National Science Foundation. (2019). *Science and engineering indicators 2020: Science and engineering labor force*. https://ncses.nsf.gov/pubs/nsb20198/.

National Science Board, National Science Foundation. (2020). *Science and engineering indicators 2020: Science and technology: Public attitudes, knowledge, and interest*. https://ncses.nsf.gov/pubs/nsb20207/.

National Science Foundation. (n.d.) *Public access to results of NSF-funded research*. https://www.nsf.gov/news/special_reports/public_access/.

National Science Foundation. (n.d.) *America COMPETES Act RECR training requirements*. https://www.nsf.gov/bfa/dias/policy/rcr.jsp.

National Science Foundation. (2011). *Ethics Education in Science and Engineering (EESE)*. https://www.nsf.gov/pubs/2011/nsf11514/nsf11514.htm.

National Science Foundation. (2018). *Building the future: Investing in discovery and innovation - NSF strategic plan for Fiscal Years (FY) 2018 - 2022*. https://www.nsf.gov/pubs/2018/nsf18045/nsf18045.pdf.

National Science Foundation. (2019). *Ethical and Responsible Research (ER2)*. https://www.nsf.gov/pubs/2019/nsf19609/nsf19609.htm.

National Science Foundation Office of the Inspector General (2020). *Semiannual report to Congress: October 1, 2019 – March 31, 2020*. https://www.nsf.gov/oig/_pdf/NSF_OIG_SAR_62.pdf.

National Science Foundation, National Center for Science and Engineering Statistics. (2019). *Women, minorities, and persons with disabilities in science and engineering: 2019.* https://www.nsf.gov/statistics/wmpd.

Nature Publishing Group. (2015). *Reporting life sciences research*. https://www.nature.com/documents/nr-reporting-life-sciences-research.pdf.

Office of Congressman Paul D. Tonko. (2021, February 3). *Tonko reintroduces Scientific Integrity Act.* https://tonko.house.gov/news/documentsingle.aspx?DocumentID=3257.

Office of Laboratory Animal Welfare (2015). *Public Health Service (PHS) policy on humane care and use of laboratory animals*. National Institutes of Health. https://olaw.nih.gov/policies-laws/phs-policy.htm.

Office of Research Integrity (2021a). *Case summaries*. U.S. Department of Health and Human Services. https://ori.hhs.gov/content/case_summary.

Office of Research Integrity (2021b). *ORI introduction to RCR*. U.S. Department of Health and Human Services. https://ori.hhs.gov/ori-introduction-rcr.

Office of Science and Technology Policy. (2000). *Federal research misconduct policy*. https://ori.hhs.gov/federal-research-misconduct-policy.

Office of Science and Technology Policy. (2019)*. Implementation of federal prize and citizen science authority: Fiscal years 2017–18*. https://trumpwhitehouse.archives.gov/wp-content/uploads/2019/06/ federal-Prize-and-Citizen-Science-Implementation-FY17-18-Report-June-2019.pdf.

Office of Science and Technology Policy. (2021, March 29). ["Dear Colleague" letter]. https://int.nyt.com/data/documenttools/si-task-force-nomination-cover-letter-and-call-for-nominations-ostp/ecb33203eb5b175b/full.pdf.

Olejniczak, A.J., & Wilson, M.J. (2020). Who's writing open access (OA) articles? Characteristics of OA authors at Ph.D.-granting institutions in the United States. *Quantitative Science Studies, 1*(4), 1429–1450. https://doi.org/10.1162/qss_a_00091.

Pain, E. (2018). Graduate students need more mental health support, study highlights. *Science*. https://www.sciencemag.org/careers/2018/03/graduate-students-need-more-mental-health-support-new-study-highlights.

Pew Research Center (2015a, January 29). *Public and scientists' views on science and society*. https://www.pewresearch.org/science/2015/01/29/public-and-scientists-views-on-science-and-society/.

Pew Research Center (2015b, February 15). *How scientists engage the public*. https://www.pewresearch.org/science/2015/02/15/how-scientists-engage-public/.

Piwowar, H., Priem, J., Larivière, V., Alperin, J. P., Matthias, L., Norlander, B., Farley, A., West, J., & Haustein, S. (2018). The state of OA: a large-scale analysis of the prevalence and impact of Open Access articles. *PeerJ Life & Environment, 6*(e4375). https://doi.org/10.7717/peerj.4375.

Popper, K. R. (1959). *The logic of scientific discovery*. Basic Books.

Prager, E. M., Chambers, K. E., Plotkin, J. L., McArthur, D. L., Bandrowski, A. E., Bansal, N., Martone, M. E., Bergstrom, H. C., Bespalov, A., & Graf, C. (2019). Improving transparency and scientific rigor in academic publishing. *Brain and Behavior*, *9*(1), e01141. https://doi.org/10.1002/brb3.1141.

Prinz, F., Schlange, T., & Asadullah, K. (2011). Believe it or not: how much can we rely on published data on potential drug targets? *Nature Reviews Drug Discovery*, *10*, 712. https://doi.org/10.1038/nrd3439-c1.

Reich, E. S. (2010). High price to pay for misconduct investigations. *Nature*. https://doi.org/10.1038/news.2010.414.

Research Integrity National Forum. (2019). *Policy statement on ensuring research integrity in Ireland* (2nd ed). http://www.sfi.ie/funding/sfi-policies-and-guidance/integrity/IUA_Research_Integrity_in_Ireland_Report_2019.pdf.

Restoring Invisible and Abandoned Trials (RIAT). (n.d). https://restoringtrials.org/.

Sacco, K., Falk, J., & Bell, J. (2014). Informal science education: Lifelong, life-wide, life-deep. *PLoS Biology*, *12*(11), e1001986. https://doi.org/10.1371/journal.pbio.1001986.

Saha, K., Sontheimer, E. J., Brooks, P. J., Dwinell, M. R., Gersbach, C. A., Liu, D. R., Murray, S. A., Tsai, S. Q., Wilson, R. C., Anderson, D. G., Asokan, A., Banfield, J. F., Bankiewicz, K. S., Bao, G., Bulte, J. W. M., Bursac, N., Campbell, J. M., Carlson, D. F., Chaikof, E. L., ...Zhou, J. (2021). The NIH Somatic Cell Genome Editing program. *Nature,* 592**,** 195–204. https://doi.org/10.1038/s41586-021-03191-1.

Sansone, D., & Carpenter, C. S. (2020). Turing's children: Representation of sexual minorities in STEM. *PLoS ONE*, *15*(11). https://doi.org/10.1371/journal.pone.0241596.

Sarewitz, D. (2016). Saving science. *The New Atlantis*, *49*, 4–40. https://www.thenewatlantis.com/publications/saving-science.

Schaeffer, K. (2020, April 23). *As schools shift to online learning amid pandemic, here's what we know about disabled students in the U.S.* Pew Research Center. https://www.pewresearch.org/fact-tank/2020/04/23/as-schools-shift-to-online-learning-amid-pandemic-heres-what-we-know-about-disabled-students-in-the-u-s/.

Scheman, N. (2001). Epistemology resuscitated: Objectivity as trustworthiness. In N. Tuana and S. Morgen (Eds.)., *Engendering Rationalities* (pp. 23-52). State University of New York Press.

Schiff, D. S., Logevall, E., Borenstein, J., Newstetter, W., Potts, C., & Zegura, E. Linking personal and professional social responsibility development to microethics and macroethics: Observations from early undergraduate education. *Journal of Engineering Education*, *110*(1), 70-91. https://doi.org/10.1002/jee.20371.

Schwartzappel, B. (2019, July 1). *Can racist algorithms be fixed?* The Marshall Project. https://www.themarshallproject.org/2019/07/01/can-racist-algorithms-be-fixed.

Stern, A. M., Casadevall, A., Steen, R. G., & Fang, F. C. (2014). Financial costs and personal consequences of research misconduct resulting in retracted publications. *eLife*, *3*, e02956. https://doi.org/10.7554/eLife.02956.

Swing, R. L. (2016). *Institutional research capacity: Foundations of federal data quality*. Association for Institutional Research.

https://www.airweb.org/resources/publications/studies-and-reports/envisioning-the-national-postsecondary-infrastructure-in-the-21st-century.

Tauginienė, L., Butkevičienė, E., Vohland, K., Heinisch, B., Daskolia, M., Suškevičs, M., Portela, M., Balázs, B., & Prūse, B. (2020). Citizen science in the social sciences and humanities: the power of interdisciplinarity. *Palgrave Communications*, 6(89). https://doi.org/10.1057/s41599-020-0471-y.

The Animal Welfare Act, Publ. L. No. 89-544 (1966). https://www.govinfo.gov/content/pkg/USCODE-2015-title7/html/USCODE-2015-title7-chap54.htm.

The College Board. (2020). *AP program participation and performance data 2020*. https://research.collegeboard.org/programs/ap/data/participation/ap-2020.

The National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research. (1979). *The Belmont Report: Ethical principles and guidelines for the protection of human subjects of research.* https://www.hhs.gov/ohrp/regulations-and-policy/belmont-report/read-the-belmont-report/index.html.

The Organisation for Economic Co-operation and Development. *PISA: Programme for International Student Assessment*. http://www.oecd.org/pisa/.

The Steve Fund. (2020). *Adapting and innovating to promote mental health and emotional well-being of young people of color: COVID-19 and beyond.* https://www.stevefund.org/wp-content/uploads/2020/09/CRISIS-RESPONSE-TASK-FORCE-STEVE-FUND-REPORT.pdf.

The White House. (2021a, January 20). *Executive order on protecting public health and the environment and restoring science to tackle the climate crisis.* https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/20/executive-order-protecting-public-health-and-environment-and-restoring-science-to-tackle-climate-crisis/.

The White House. (2021b, January 27). *Memorandum on restoring trust in government through scientific integrity and evidence-based policymaking*. https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/27/memorandum-on-restoring-trust-in-government-through-scientific-integrity-and-evidence-based-policymaking/.

The United Nations Committee on Economic, Social and Cultural Rights (2020). *General comment No. 25 (2020) on science and economic, social and cultural rights (article 15 (1) (b), (2), (3) and (4) of the International Covenant on Economic, Social and Cultural Rights)*. The United Nations. https://docstore.ohchr.org/SelfServices/FilesHandler.ashx?enc=4slQ6QSmlBEDzFEovLCuW1a0Szab0oXTdImnsJZZVQdxONLLLJiul8wRmVtR5Kxx73i0Uz0k13FeZigChAWHKFuBgp%2B4RaxfUzqSAfyZYAR%2Fq7sqC7AHRa48PPRRALHB.

Tilghman, S., Alberts, B., Colón-Ramos, D., Dzirasa, K., Kimble, J., & Varmus, H. (2021). Concrete steps to diversify the scientific workforce. *Science*, *372*(6538), 133-135. https://doi.org/10.1126/science.abf9679.

Torres, I., Watkins, R., Liukkonen, M., & Neo, M. L. (2020). COVID has laid bare the inequities that face mothers in STEM. *Scientific American*.

https://www.scientificamerican.com/article/covid-has-laid-bare-the-inequities-that-face-mothers-in-stem/.

Union of Concerned Scientists. (2018, January 18). *Abandoning science advice*: *One year in, the Trump administration is sidelining science advisory committees*. https://www.ucsusa.org/resources/abandoning-science-advice#ucs-report-downloads.

Union of Concerned Scientists (2020a, September). *The scientific integrity roadmap: Recommendations for 2021 and beyond for building up science across the federal government*. https://www.ucsusa.org/sites/default/files/2020-09/scientific-integrity-roadmap.pdf.

Union of Concerned Scientists (2020b, September). *Scientific integrity of federal advisory committees: Recommendations for 2021 and beyond*. https://www.ucsusa.org/sites/default/files/2020-09/si-of-federal-advisory-committees.pdf.

United States Department of Education Institute of Education Sciences National Center for Education Statistics. (n.d.) *About IPEDS*. https://nces.ed.gov/ipeds/about-ipeds.

United States Department of Education Institute of Education Sciences National Center for Education Statistics. (2019). *An overview of NAEP*. https://nces.ed.gov/nationsreportcard/subject/about/pdf/NAEP_Overview_Brochure_2018.pdf.

United States Department of Education Institute of Education Sciences National Center for Education Statistics. (n.d.) *IPEDS: Purpose and uses of survey data*. https://surveys.nces.ed.gov/ipeds/public/purposes-of-survey-data.

United States Department of Education Institute of Education Sciences National Center for Education Statistics. (2021). *National assessment of educational progress: Assessments.* https://nces.ed.gov/nationsreportcard/assessments/.

United States Department of Education Institute of Education Sciences National Center for Education Statistics. (n.d.) *Trends in International Mathematics and Science Study (TIMSS)*. https://nces.ed.gov/timss/overview.asp.

United Nations Educational, Scientific, and Cultural Organization (UNESCO). (2017). *Records of the General Conference, 39th session, Paris, 30 October-14 November 2017*. *v.1: Resolutions*. https://unesdoc.unesco.org/ark:/48223/pf0000260889.

United States Census Bureau. (n.d.) *About the American Community Survey*. https://www.census.gov/programs-surveys/acs/about.html.

United States Census Bureau. (n.d.) *Why a census?* https://www.census.gov/programs-surveys/decennial-census/2020-census/about/why.html.

United States Census Bureau. (2019). *QuickFacts: United States* [Data table]. https://www.census.gov/quickfacts/fact/table/US/IPE120219.

United States Commission on Civil Rights. (2017). *Working for inclusion: Time for Congress to enact federal legislation to address workplace discrimination against lesbian, gay, bisexual, and transgender Americans*. https://www.usccr.gov/pubs/docs/LGBT_Employment_Discrimination2017.pdf.

United States Department of Education Civil Rights Data Collection. *Frequently asked questions*. https://ocrdata.ed.gov/assets/downloads/FAQ.pdf.

United States Department of State. (2011). *About the U.S. and UNESCO*. https://2009-2017.state.gov/p/io/unesco/usunesco/index.htm.

United States Food and Drug Administration. (2019). 2*018 drug trials snapshots summary report*. https://www.fda.gov/media/120253/download.

University of Washington Health Sciences/UW Medicine. (2014, August 15). Personal, public costs of scientific misconduct calculated. *ScienceDaily*. www.sciencedaily.com/releases/2014/08/140815102229.htm.

Ushomirsky, N., & Williams, D. (2015). *Funding gaps: Too many states still spend less on educating students who need the most*. The Education Trust. https://edtrust.org/wp-content/uploads/2014/09/FundingGaps2015_TheEducationTrust1.pdf.

Van Noorden, R. (2011). Science publishing: The trouble with retractions. *Nature, 478*, 26-28. https://doi.org/10.1038/478026a.

Wagner, W., Fisher, E., & Pascual, P. (2018). Whose science? A new era in regulatory "science wars." *Science*, *362*(6415), 636-639. https://doi.org/10.1126/science.aau3205.

Wang, Y., Kaplan, N., Newman, G., & Scarpino, R. (2015). CitSci.org: A new model for managing, documenting, and sharing citizen science data. *PLoS Biology*, *13*(10). https://doi.org/10.1371/journal.pbio.1002280

Washington, H. (2006). *Medical apartheid: The dark history of medical experimentation on Black Americans from colonial times to the present*. Doubleday.

West, D.M., Villasenor, J., and Schneider, J. (2017). *Private sector investment in global health R&D: Spending levels, barriers, and opportunities*. The Brookings Institution. https://www.brookings.edu/wp-content/uploads/2017/09/private-sector-investment-in-global-health-rd_final.pdf.

West, S. M., Whittaker, M. & Crawford, K. (2019). *Discriminating systems: Gender, race and power in AI*. AI Now Institute. https://ainowinstitute.org/ discriminatingsystems.html.

Wieseler, B., & McGauran, N. (2020). From publication bias to lost in information: why we need a central public portal for clinical trial data. *BMJ Evidence-Based Medicine*. http://dx.doi.org/10.1136/bmjebm-2020-111566.

Woolston, C. (2020). "It's like we're going back 30 years": how the coronavirus is gutting diversity in science. *Nature*. https://www.nature.com/articles/d41586-020-02288-3.

Zamudio-Suarez, F. (2021). Minority students aren't getting the mental-health care they need. Here's how to help. *The Chronicle of Higher Education*. https://www.chronicle.com/newsletter/race-on-campus/2021-01-12.