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SCIENCE POLICY

Pathways for diversifying and enhancing science advocacy

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Science is under attack and scientists are becoming more involved in efforts to defend it. The rise in science advocacy raises important questions regarding how science mobilization can both defend science and promote its use for the public good while also including the communities that benefit from science. This article begins with a discussion of the relevance of science advocacy. It then reviews research pointing to how scientists can sustain, diversify, and increase the political impact of their mobilization. Scientists, we argue, can build and maintain politically impactful coalitions by engaging with and addressing social group differences and diversity instead of suppressing them. The article concludes with a reflection on how the study of science-related mobilization would benefit from further research.

INTRODUCTION

Emerging inside and outside scientific institutions and other science-related spaces, science advocacy has a long history of mobilizing scientists in the public arena when they see public policy veer away from the wisdom of scientific findings. The mobilization of scientists as a political force gained renewed prominence during the March for Science on 22 April 2017, when more than a million participants in 600 cities worldwide marched to support scientific research and science-informed policy-making. During the 2020 Black Lives Matter uprising that followed the killing of George Floyd at the hands of police, many scientific institutions and organizations in the United States felt pressures to confront the long history of exclusion and violence against marginalized groups in scientific research, training, and advocacy by releasing formal statements of support for social and racial justice. Today, anti-science political forces endure, climate denialism and threats to scientific integrity persist, the pandemic has become a regular feature of life, and racial and social justice conflicts within and beyond the academy continue to loom large. The overlapping political, economic, social, and public health crises of the past 6 years raise important questions about the efficacy and impact of science advocacy: How can science advocates, that is, scientists and their allies in education, health, and other science-adjacent fields, sustain their activism, build inclusive leadership, diversify academic and scientific organizations, and enhance the impact of science-related organizing? How can advocates for science better center equity and justice within science and science-based policy?

This article synthesizes work from social movement research, the sociology of science, and science and technology studies to assess the justice, equity, diversity, and inclusion dimensions of science advocacy and the range of actions constitutive of science-related mobilization. The definition of who "counts" as a scientist is complex and contested, but for our purposes, a scientist is a person that has formal credentials and training in a scientific discipline (including the social sciences and engineering) and who works in a science/engineering occupation. Our starting premise is that science, as well as the politics that emanate from it, is not monolithic. Rather, we recognize that scientist advocacy and mobilization are diverse, representing a range of goals, strategies, and forms of engagement. The organizations, networks, and actors engaging in varied forms of mobilization are heterogeneous and context dependent, creating and responding to distinct opportunities and challenges (*1*). In turn, each entity's relationship to power shapes how they make meaning, define their own agency, and pursue collective action (*2*). In seeking to promote policies informed by scientific wisdom, scientists can turn directly to exert influence within political institutions and, as an alternative or a complement, educate and mobilize a broader public to engage in politics. Effective democratic mobilization of science entails negotiating a balance between technocratic guidance and civic education, a balance that's difficult to achieve. We see a pressing need for further research that examines opportunities and constraints within scientific organizations and institutions, including work that provides insight into how different kinds of organizations and institutions shape the science advocacy that emerges from or reverberates through those activist spaces.

We begin by introducing ways in which science-related mobilization takes place and its social and political relevance. We follow with a discussion of the social conditions shaping science advocacy. Next, we discuss how science organizations and advocates can respond to calls to address their histories of exclusion and harm against marginalized communities. We then review research on the challenges and benefits of adopting organizing approaches that prioritize the leadership of marginalized groups and their issues. We continue by reviewing research that points to how mobilization can increase its political impact. We conclude by reflecting on areas within the study of mobilization around science-related issues that would benefit from further research.

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SCIENTISTS IN THE POLICY-MAKING PROCESS

Over the past 50 years, the dilemmas attendant to scientific expertise with public policy in a democracy appear to have only become more acute (*1*). Moreover, with the explicit anti-science platform of the Trump presidency, scientists plunged into the policy maelstrom by mobilizing their expertise, social networks, and professional status to shape policy decisions on a wide range of political issues (*3*). Scientific input, including, in some cases, scientists' resistance, is likely critical in effective efforts to confront contemporary policy problems.

This is not the first time scientists have mobilized on such a scale. The broader movement for nuclear arms control was instigated by scientists like Albert Einstein who made public statements warning against nuclear technology and weaponry when their direct advice to policy makers was ignored. (*4*). He joined a broader scientists' movement for nuclear arms control, going public with their professional expertise and status because they could not prevail with direct advice. By engaging in activism in this way, scientists in the movement hoped to seed broader public opposition for nuclear weapons and influence political authorities (*5*). Scientists in the movement attempted to trade on their scientific expertise and status to advocate on related political and moral issues such as arms control. More recently, we have seen similar patterns of science engagement around the issue of climate change. This type of advocacy persists despite strong professional norms against it as many believed it compromised scientific "objectivity."

This example of scientific engagement in the nuclear weapons issue crystallizes much of the scientific advocacy dilemmas that remain today. Concerns about the use and misuse of science animated the creation of longstanding science advocacy organizations like the Union of Concerned Scientists (UCS) (*6*). UCS emerged in 1969, calling for popular participation in decision-making processes involving the use of scientific knowledge, initially in opposition to the Vietnam War. UCS and other scientific groups have been particularly visible in debates about nuclear power, nuclear weapons, and climate change. In the wake of the 2016 election of Donald Trump, UCS grew its "Science Network" to a historic high of 26,000 supporters.

In these ways, the challenge of science advocacy came to include a substantial dose of public engagement and education. Scientists warn, advise, advocate, and educate to support their preferred positions. They not only work through professional connections but also deploy status and institutional resources to gain broader audiences. They often connect with social movements and start expert organizations of their own to advance their concerns. Like the atomic scientists, advocates and scientists often forge transnational links and organizations, promoting global change and external pressures on their own governments (*7*). Science advocates can affect the development of a political issue by framing the stakes of a particular problem.

At the same time, science advocacy is happening within the formal political process. President Franklin Roosevelt first established an official scientific advisory committee led by a president's scientific advisor, a position that the Biden administration temporarily elevated to a cabinet-level position status. In this context, scientists can advocate for policy change by identifying new problems, promoting solutions, or foreclosing others. They can mobilize privately, testify before policy-makers, or try to reshape the policy domain on a particular issue (*8*). A record number of candidates with STEM (science, technology, engineering, and mathematics) backgrounds ran for Congress in 2018 (*9*). This means that scientists can play a role in both agenda setting, that is, deciding what must be decided, and formulating responses, but in democracies, those unsatisfied with the way a political debate is going always have an interest in expanding the scope of decision-making and bringing in new actors (*10*), so scientists can work to educate and organize a broader public by going public. In what follows, we consider ways in which scientists, often in conjunction with nonscientist movements, exert political influence and how their efforts sometimes matter. We detail the state of knowledge of how science-related mobilization can address pressures to diversify, sustain coalitions across difference, and the political consequences of doing so.

CONDITIONS SHAPING SCIENCE ADVOCACY

Efforts to mobilize scientists and science advocates can benefit from existing organizations and networks that enable and facilitate interactions among different groups. However, mobilizing across different groups is challenging. Below, we provide insights on how science advocates can mobilize and sustain mobilization in contexts of social group difference. We point to networks and organizations as drivers of mobilization and approaches to building activism and solidarity that help movements cope with social group differences.

Networks and organizational drivers of mobilization

Connections among the individuals and organizations involved in activism and advocacy, their social networks, play an essential role in who participates and what form the activism takes (*11*). As boundary-spanning structures, networks that run through science advocacy organizations or community-science alliances distribute specialist knowledge, institutional experience, technical skills, and social authority into social movements (*9*, *12*). By bridging previously unconnected professional and activist communities and thickening ties between social movements and professional science, expert networks can alter the size and structure of social movement fields. They can also operate inversely as conduits for movement-based resources, integrating collective action frames and discourses, organizing strategies, and political experience into professional and disciplinary communities (*13*).

Professional organizations, including scientific societies and public interest science organizations such as UCS, provide important resources—intellectual, material, and social—to scientific communities (*14*). While many scientific associations are structured to advance the collective interests of particular disciplines, specialties, or research areas, others advance their members' social and political interests, connecting scientific communities to the larger society (*15*). Of course, professional and political interests are not mutually exclusive, and some organizations accommodate both. Science advocacy organizations facilitate scientists' mobilization into political action, while their formal status as professional groups can shield activist scientists from professional sanction and political backlash (*6*). Science advocacy organizations draw support from formal and informal networks of scientists and influence the structure and dynamics of those networks. Candidates for Congress with STEM backgrounds during the 2018 midterm election were more likely to survive their primaries and advance to the general election when they were endorsed by 314 PAC, an advocacy

group that promotes and supports candidates with STEM backgrounds (*9*).

In seeking influence on policy, advocates must find a way to build solidarity with others like them, as well as with a broader public. Social solidarity is the collective feeling of shared membership within a group: the emergent "we" feeling that the group is unified and enjoined in a common purpose (*16*). It is generated through activists' collective participation in high-intensity social interactions such as protest marches, sit-ins, and other demonstrations and by creating and organizing around collective symbols. For instance, Science for the People members used the red fist symbol to represent themselves while building internal solidarity and drawing attention to their cause by disrupting high-profile scientific meetings (*6*). Solidarity imbues activists with confidence in their cause and commitment to their movement and promotes courage in the face of resistance from conflicting movements or the public. It is also crucial for developing new ideas, concepts, and collective action frames from which social movement ideologies are generated (*17*). For these reasons, movements in science with high levels of solidarity generally improve their chances of realizing their goals (*18*).

The cycle of science activism initiated in the wake of the Trump election in 2016 opens opportunities for innovation of political action and deepening engagement in science advocacy (*19*). However, organizers must find ways to cope with the challenges of igniting and sustaining activism to seize opportunities for broader mobilization and deepen engagement. A key challenge is organizing in the context of social and identity group differences. Next, we discuss research on intersectional approaches to organizing that can inform building solidarity across differences in science advocacy and help advocates cope with the challenges of adopting intersectional organizing approaches.

ADDRESSING EXCLUSION THROUGH INTERSECTIONAL SOLIDARITY

Science advocates can draw insights from historical and existing organizing efforts that seek to address power asymmetries among social groups engaged in organizing. These insights can help prioritize issues affecting marginalized groups, support their leadership, and deepen their inclusion within science advocacy organizing spaces. This is important because single identity-based movements and coalitions often neglect the issues of multiply marginalized subgroups (*20*), also known as intersectionally marginalized groups (*21*). In this view, science advocacy that only attends to one axis of oppression excludes those whose lives are shaped by multiple interacting systems of oppression from organizing agendas and the policies that they seek to realize. Thus, single-axis approaches to politics can lead to policy silences whereby multiply marginalized groups are neglected (*22*).

The Combahee River Collective Statement (*23*) is among the most notable critiques of this exclusion and neglect of single-axis-oriented organizing. The Combahee River Collective, made up of Black women scholars and activists (including Audre Lorde, Barbara Smith, Beverly Smith, Demita Frazier, Chirlane McCray, Akasha Hull, Margo Okazawa-Rey, and Cheryl Clarke), was critical of the relegation of Black women to the margins within civil rights and second-wave feminist organizations. Rather than calling for separate movements, the Combahee River Collective called on existing movements to shift their organizing approach to address the exclusion of multiply marginalized groups. This call reverberated within and outside academic settings.

The perspectives forwarded in the Combahee River Collective statement were an early articulation of the ideas that motivated the coining of the term "intersectionality" by Kimberlé Crenshaw (*22*). Intersectionality is both a political project and a form of conceptualizing oppression that recognizes that marginalization stems from multiple interacting systems of oppression. This project emerged at the juncture of academic and social movement spaces (*24*, *25*), aiming to forward more nuanced understandings of marginalization and articulate a different approach to building social movements, democratic institutions, and practices (*24*, *26*–*29*). The intersectionality project also decries the subjugation of political thought emerging from marginalized groups, both within social movements and academia (*28*–*33*). However, these ideas have yet to inform widespread changes within scientific institutions and science advocacy organizations.

Intersectional approaches to organizing

Those promoting intersectional understandings seek a form of solidarity that prioritizes the issues of marginalized groups. In the case of science advocacy and activist movements, scholar-activists have called for intersectional forms of solidarity to address the scientific community's history of excluding and causing harm to marginalized communities (*34*). Intersectional approaches to organizing entail building ties across social group differences while negotiating power asymmetries between them (*35*–*39*). The project of intersectionality forwards an approach to building mobilization that places emphasis on addressing power imbalances within movements by adopting measures to prioritize the issues of multiply marginalized groups in movement agendas, fostering their leadership, making space for their autonomous organization, and avoiding suppressing difference and dissent (*20*, *36*, *38*, *40*–*42*).

Social movement scholarship examines the organizing implications of intersectionality, its increasing popularity among activists, and how intersectionality shapes movements and their political impact (*24*, *29*, *43*). Addressing social group differences and diversity, instead of suppressing them, is essential for building and sustaining coalitions (*36*, *44*–*47*). Some consider intersectionality a form of movement discourse that motivates collective action and coalition building (*48*, *49*). Protesters associated with the so-called Resistance to the Donald Trump presidency, for instance, reported multiple social justice issues as their motivation for participating (*49*, *50*). Elliot *et al.* (*51*) argue that identity bridging, a process whereby movements link multiple identities, is an effective recruitment tool for movements. Movement intersectionality is a dynamic process that can generate new collective identities, new understandings of social problems, and new movement practices (*50*, *51*, *52*). These collective identities, forged in contention and mobilization, are consequential for sustaining activism in contexts of social differences (*45*, *55*, *56*).

Movements adopting intersectional organizing approaches engage in efforts to gain an intersectional understanding of marginalization and build organizing approaches that seek to subvert marginalization within movements and across societal institutions (*57*, *58*). Movements can engage in deliberations and processes that fashion understandings of oppression and identities, including intersectional ones, that shape their organizing. Intersectional

consciousness emerges at individual and collective levels and can enable organizing in contexts of high social group diversity because it generates intragroup solidarity (*35*, *41*, *59*–*62*), fosters new alliances (*63*), and intensifies activism (*54*). The study of structural inequality in the field of science and technology studies has experienced a reemergence since 2000 and holds the potential to inform the development of intersectional consciousness in the sciences (*64*), grounded in structural understandings of oppression and inequality.

Bridge-builders engage in labor to develop collective intersectional consciousness within movements and across movement coalitions (*46*, *65*). This labor of bridge-building and brokerage, which Doerr (*66*) calls political translation, is often taken up by intersectionally marginalized groups (*54*, *67*, *68*). When this labor is impactful, a movement's praxis, that is, reflection-informed social action, reflects an awareness of marginalization through an intersectional lens.

Intersectional solidarity in science advocacy

Science and science advocacy have a documented history of excluding women and minorities and harming marginalized groups (*69*–*72*). Despite making some progress, inclusion issues continue to challenge science advocacy groups. Survey research found that the March for Science was among the least diverse protest events associated with the Resistance movement against President Trump (*48*). However, in recent years, science advocacy movement organizations, leaders, and organizers are under pressure (*73*) to build a movement more responsive to the issues of marginalized communities and more representative of scientists from social group backgrounds historically excluded from the sciences.

There are numerous indicators of these increased pressures. The emergence and growth of the Black Lives Matter movement and the 2020 uprising in the wake of the police killing of George Floyd have been sources of encouragement among science advocates and ignited calls for change in the sciences (*74*). To be sure, recognizing the moral wrong of police violence does not require much in the way of scientific expertise, but the recorded video of an egregious instance of such violence underscored the shadows of social and political structures on varied experiences and expertise. During the attendant political uprising, the scientific community, along with nongovernmental organizations engaged in science advocacy, stood in solidarity with the movement through different tactics (*75*) [see also (*43*)]. Numerous scientific societies, universities, academic departments, and science advocacy organizations took time to reflect on how systemic racism has affected them and issued statements recognizing their own racist history, decrying the killing of George Floyd, and to varying degrees, calling for action to end violence against Black people (*76*–*78*). Peer-reviewed journals and scientific news outlets ran editorials, perspective articles, and published peer-reviewed articles that recognized the histories of racism in the sciences, pledged to act, and outlined plans to fight racism (*53*, *79*, *80*).

For some, however, statements of solidarity (*73*) were not enough (*81*), and they instead called on scientific organizations and science advocates to commit to enacting intersectional solidarity (*81*). Recent critiques of newer organizations like the March for Science push science advocacy organizations to address the challenge of inclusivity and take the organizing implications of intersectionality seriously (*34*). Science advocates have been pressed to build on existing intersectional solidarity organizing efforts within the academic community, such as campaigns to organize academic worker unions (*82*) and student movements engaged in decolonial and anti–tuition hike struggles (*41*, *83*).

The science advocacy movement can build on the perspectives and organizing efforts of intersectionally marginalized scholars and communities. TallBear (*84*) articulates an Indigenous feminist standpoint, through which Indigenous scientists and scholars can mobilize within academic spaces "to do some strategic repair in the world." Situated knowledges can inform and lead bridge-building work within movements and within broader societal institutions. However, this bridge-building labor must be recognized, valued, compensated, and equitably distributed if it is sustainable and transformative. Science advocacy groups can also promote fields that emerge from movements and cultivate scholar-activism in the pursuit of social justice, such as Black studies (*85*), feminist technology studies, and Native American and Indigenous studies (*84*). These fields intersect with the study of structural inequality within science and technology studies. Reciprocally, the reemergence of attention to structural inequality within science and technology studies can inform science-related mobilization aimed at igniting social change. Furthermore, scientific societies and science advocacy organizations can mobilize their members to engage in science advocacy, promote intersectional forms of solidarity, and support the growth of science advocacy groups under the leadership of marginalized scientists, such as Reclaiming STEM (*86*).

However, efforts to build inclusive organizing are not without challenges. The extent to which intersectional frames benefit movements is debatable. Intersectional frames refer to understandings of social problems that movements fashion in ways that link issues affecting multiply marginalized groups. While some argue that intersectional frames increase movement support and enhance recruitment among youth (*51*), others find that intersectional framing decreased support for the Black Lives Matter movement (*83*). Furthermore, enacting intersectional solidarity can require engaging in internal movement conflict and investing considerable energy, time, and resources to address power imbalances (*29*, *38*).

However, intersectional forms of solidarity within and across movement organizations can enhance a movement's chances of survival over time and increase its legitimacy, political influence, and ability to innovate (*41*, *84*–*88*) . Efforts within the Women's March to include women of color in the organization's leadership, an element of intersectional solidarity, elicited sustained participation in the movement (*89*). Science advocacy can diversify and meet pressures to address its histories of exclusion insofar as organized efforts can cope with the challenges of organizing across differences. Coping with internal differences can help movements improve their political influence (*42*). Next, we discuss research that points to pathways for enhancing the political influence of science advocacy.

KEYS TO SCIENCE ADVOCACY POLITICAL INFLUENCE

The efficacy of social movement campaigns, protests, and tactical repertoires can often depend on how political advocacy is organized, whether concentrated or diffuse, individualistic or collective, ad hoc or formalized (*90*). This point also applies to science advocacy [see (*91*)]. Scientists and communities can engage in multiple forms of mobilization to achieve political influence. Here, we review

keys and challenges to science advocacy political influence, including coalition building among scientists and with communities, data justice work, leadership and organizational development, and public engagement and advocacy.

Coalition building with communities

When communities build coalitions with researchers or scientific organizations, they become linked to science production, stand to shape and benefit from new scientific discoveries, and exert political influence (*92*). By community, we refer to a residential area defined geographically (e.g., a town or neighborhood) or a set of interdependent relationships between individuals electing to come together over a shared identity, lived experience, or purpose, such as when patients, activists, and researchers work to improve the diagnosis and treatment of a disease. Coalition building between scientists and communities is possible with an early and earnest commitment to forming a partnership that offers not only the opportunity for knowledge production but also tangible outcomes that are defined by community members and, accordingly, can be observed at the community level (*92*). The contours of different activist campaigns generate disparate alliances and targets.

Coalitions are also important for challenging existing structures of knowledge production that overlook, exclude, or exploit communities (*92*–*94*). AIDS activism in the United States in the 1990s is a telling example of how communities understand the exploitative nature of some scientific work and are excluded from science through the policing of boundaries around who counts as having legitimate knowledge. As illustrated by Steven Epstein's classic study, AIDS activists successfully pushed scientists and regulators to open clinical trials of experimental drugs to a broader cross section of individuals and informed the design of these trials by becoming experts in their own right and lobbying to have their voices included in the research process (*95*).

For scientists, coalitions with community members are an opportunity to gain new perspectives on old research problems, design more innovative projects, collect new kinds of data, and ensure more reliable data collection from community members. For communities, these coalitions are a potential pathway to social change insofar as conducting science together becomes a way of organizing people, and the results of scientific inquiry can be used to confront existing environmental conditions or social, political, and economic structures (*96*).

Notably, coalitions are more easily created when a community's epistemologies, standards for data collection, and processes of meaning-making are congruent with mainstream "Western" science. It is more challenging when communities use vastly different criteria for what counts as evidence (*97*) or when scientists entering collaboration are unaware or unwilling to confront the values underlying their research designs and methodologies (*98*–*100*). Some collaborations between scientists and communities, for example, will require negotiation about how much of a role local or Indigenous Peoples knowledge will play in knowledge production and how it will be evaluated next to scientific data collection and analysis (*101*). Appending local testimony to a project is barely sufficient as a form of meaningful input. Instead, mechanisms must be put in ahead of time to decide how "nonscientific" forms of knowledge production will fit within the more standard scientific framework for drawing conclusions and making decisions (*102*). While engaging communities is vital to the future of science and democracy, we want to be careful not to construe all alliances and collations as "good" for science, by definition. Such alliances can undermine scientific discovery when they are used to advance overt ideological and religious positions, such as in the case of the Catholic Church aligning with pro-life groups to restrict research on oocytes [see (*103*)].

At the heart of community-based research and coalition building is identifying the "who counts" in communities. It is not necessarily straightforward, as evidenced by Ruha Benjamin's work on stem cell research, which reveals the "fundamental ambiguity about who 'the people' of participatory science initiatives are and should be." (*103*). Individuals and groups most ready to engage in partnerships are typically the most organized and have the most resources but are not necessarily the only groups that would benefit from being involved. It takes time, patience, and work to locate groups who fundamentally distrust experts or cannot participate because of constraints in their lives that make participation stressful and onerous. As Benjamin's research shows, non-white racial and ethnic groups have had to lobby regulators and scientists to be included in clinical trials, yet at the same time, some individual members of these groups resist participating, given the long history of abuse and exploitation of racial and ethnic minorities in biomedicine (*103*, *104*). Experts become frustrated and fall back on racial generalizations that essentialize racial and ethnic groups in their search for "diverse" research participants (*104*). To overcome these dangerous "blind spots" and biases in research, experts must be willing to learn more about the social, economic, and political histories and life experiences of potential research participants and work to build trust and put in the work to form a meaningful collaborative relationship with them (*105*).

Challenges and strategies for coalition building with communities

In decolonial, collaborative work, research teams must be diverse and include community members as co-producers of knowledge, not just research partners (*102*, *106*). Diversity must not be limited to tokenized participation and, instead, must build spaces that enable the meaningful participation of historically excluded communities and scientists in collective decision-making. Furthermore, organizing around science benefits from promoting community leadership and embracing the knowledge that emerges within communities (*107*). This kind of collaboration is at odds with the institutional structure and culture of academic science, and funding this work and publishing it can be challenging (ibid.).

The foundation of coalition building among scientists and communities must be pursuing "knowledge justice," which refers to applying social justice principles in contexts where knowledge is produced, especially when knowledge formation is inequitable (*99*). In practice, this means taking seriously the publics affected by scientific knowledge production while also including them as potentially valuable producers of knowledge. Too often, such publics are asked to step aside so that experts can have their questions answered and their models of understanding prioritized (*94*, *108*). Allen (*109*) outlines six ways that community-based research striving for knowledge justice can proceed: First, researchers should find out what questions community residents have and why they have these questions. Researchers should be forthright about what kinds of data and scientific approaches can answer these questions and be transparent about their ability to influence policy outcomes.

Data analysis should proceed with community members as active participants, and the final report should foreground community input and support community members in promoting the findings and policy implications (*109*).

Engaging with communities also entails recognizing the value-laden dynamics that mark the sciences. As philosopher of science Sandra Harding (*110*) argues, "Sciences and their philosophies have never been value-free. They have always been deeply integrated with their particular social and historical contexts." Objectivity and diversity are not deeply at odds; rather, they reinforce one another. The best evidence of their mutuality can be found in feminist and postcolonial studies of science and technology that situate research questions, data collection, and interpretation in the very communities where scientific research is taking place. Scientific studies that reject diversity and the situatedness of knowledge in the name of pursuing objectivity will find only partial answers to pressing research questions at best and wrong answers at worst (*84*). Harding uses development projects in the global south to show how the relentless pursuit of objective social science resulted in the systematic failure to capture the relationship between gender and power relations in land access, care work, and survival, meaning that millions of dollars of development work have little discernible positive impact on poor and marginalized communities.

The claim that pure science is objective and insulated from power has been tested in other ways, such as when laypeople demand recognition of their expertise and demand a place at the table in scientific research. Science has also diversified through conflict over acceptable bodies of evidence used to rationalize current or proposed industrial operations. This is especially visible in the past three decades of widespread activism and concern about toxic exposures when community members had little opportunity to get the necessary information and assistance in public action (*111*, *112*). In 1982, a Black community in Warren County, North Carolina organized against toxic waste dumping in their region, launching the modern environmental justice movement, which bridged civil rights and toxic waste activism (*113*). This movement can also be traced to Latinx, Indigenous, and Asian communities, which have consistently fought back against the siting of noxious facilities in their backyards [see, e.g., (*114*, *115*)]. Lois Gibbs' organizing at Love Canal in New York state in the early 1980s is another foundational example of laypeople engaging with science to challenge the status quo (*116*). Organizing around the toxic pollution in the community of Love Canal compelled President Jimmy Carter to visit the town and lay plans for the Environmental Protection Agency to launch its Superfund cleanup program for toxic waste sites. These campaigns and the success of these alliances point to the power of intersectional approaches to coalition building that prioritize the issues of marginalized groups.

Communities are often on the receiving end of knowledge production and technological development but have changed the terms of knowledge production and evidence-gathering through conflicts with scientific and technological experts. Popular epidemiology, the process through which laypeople frame the research question, collect and analyze data, and set the parameters for making claims about public health, is just one example of this (*108*, *117*). People with little or no science background have been able to marshal the resources of science to win a variety of victories: buy-out of contaminated areas, economic settlements from polluting companies, regulation and abolition of dangerous chemicals, government and corporate toxics use reduction, health monitoring for people in toxic-affected areas, restrictions on oil refinery flaring, the substitution of cleaner vehicles, participation in decision-making about siting of hazardous facilities, membership on peer review panels for environmental health research, and participation in governmental and quasi-governmental (e.g., National Academies of Sciences, Engineering, and Medicine) committees and task forces (*118*).

The structures and institutions that contribute to a generally accepted view of disease are not always visible to communities until residents run up against the dominant epidemiological paradigms shared and produced by these institutions (*119*). These paradigms refer to the embedded set of beliefs and practices about a disease and its causation and are found within established institutions entrusted with the diagnosis, treatment, and care of disease sufferers, such as medical doctors and health professionals, medical researchers, public health agencies, and medical insurance agencies, as well as journals, media, universities, medical philanthropies, and government officials. Typically, these paradigms are centered on the primacy of individual causes, and often, of personal responsibility, while ignoring the toxic effects of industrial production, poor access to care, many forms of social deprivation, and other institutional features of a stratified society. In opposition to this paradigm, challengers pose what Krimsky (*120*) calls public paradigms, a pattern of public debate and action on alternatives to current scientific and societal processes. His prime example was public debate over what was then called the "endocrine disruption hypotheses" pioneered by Theo Colborn, which posited that many chemicals affected multiple endocrine system functions, including many low-dose and nonmonotonic relationships. What was initially a new and controversial hypothesis with its research largely unfunded and frequently rejected from journals, is now a major focus of environmental health research. Critical epidemiologists who consider race, class, economics, and political power as substantial factors in disease also contribute to support for communities (*121*). On the basis of the work of Steve Wing (*122*), critical epidemiologists support community groups in conducting original research on environmental health effects, pushing government agencies to support such work, and criticizing harmful or incomplete governmental agency responses.

Effectively engaging diverse communities in scientific processes and politics affects the questions and problems that scientists address and the methods that they use to address them and expands the range of information that scientists, as well as broader publics, regard as data. As laypeople became more fluent in using science, they also had to guard against scientized views, wherein seemingly objective notions of science that frame political and moral questions in scientific terms and prioritize the legitimacy of scientific actors, thereby limiting public participation, and delegitimizing the importance of those questions (e.g., around culture and social factors) that are considered irrelevant to scientific analysis (*123*, *124*). For example, Kinchy documents how farmers in Mexico built relationships with international experts to combat the federal government's narrowly scientized approach to policies promoting genetically engineered maize crops (*119*). Nevertheless, scientization is not identical to reliance on science but is an approach that argues for a value-free science that removes affected people and communities from deliberation. Scientization also presses for continual research even when the science is well

enough established that affected people demand concrete action. Lay action seeking reliance on science is necessary when citizens are deemed anti-science by virtue of their social position, such as in the case of women in Fukushima Prefecture in Japan fighting for better radiation measurement after the Fukushima Daiichi nuclear reactors meltdown of 2011 (*125*).

Civic science has been another major source of challenges to traditional sciences. In areas where governments have largely supported polluters and where scientists have done little research, groups like Global Community Monitor, Louisiana Bucket Brigade, Shale Test, and Public Lab have used low-cost community monitoring instruments that enable people without a scientific background to analyze emissions and contamination from oil and gas operations. This often consists of a multifaceted approach that includes quantitative measurements of pollutants and qualitative health experiences, stories, pictures, and videos, not only redefining what is considered environmental health data (*122*) but also introducing new ethical considerations in how research is designed, conducted, and communicated (*126*). Civic science can involve citizen-science alliances and lead to new scientific data, shifts in scientific thinking, and challenges to science policy. This has happened in the vibrant environmental health and justice movement that brings together voices and approaches from the civil rights, women's, environmental, environmental justice, and other movements (*127*). In the United States, the National Institute of Environmental Health Sciences has been a major funder of community-based participatory research in the environmental health arena, providing opportunities for not only good science but also capacity building for community organizations.

Leadership, organizing, and resourcefulness: Climate change as an exemplar

To understand the effectiveness of social movements and activism, scholars have worked to understand how leadership is related to the forms and function of organizing, as well as its outcomes [for an overview, see (*128*, *129*)]. Scientists often work with individuals and movements to affect social change broadly. Recent research has explored how the pursuit of science and the scientific process mobilized participation by scientists and others in the wave of activism against the Trump Administration and its policies (*3*, *19*, *130*). During this period of heightened activism and advocacy, attention grew around the issue of climate change, where activists and organizations have embraced science and the work of scientists. In this section, we use the case of climate change to discuss leadership and organizing in science advocacy.

The challenges of creating a global movement for effective political action on climate change are extensive and well-known (*131*). Specialist scientists were the first to recognize the threat presented by more than a century of production and discharge of greenhouse gases into the environment [for an overview of the history, see (*132*)]. Scientists served as initiators of public education campaigns, sometimes in professional scientific publications, sometimes in formal courses at colleges and universities, and sometimes through testimony before governmental bodies. The disconnect between the extremely limited political progress to recognize and then act on the threat of climate change and the increasingly dire scientific findings regarding how the world would change because of anthropogenic climate change motivated activism by scientists and others [for an overview, see (*133*)].

However, getting the word out and engaging civilians in the effort to institute new policies was extremely difficult. First, the science was complex, and the dangers identified varied markedly. Second, the time horizon seemed distant and did not match well with the timeline of an electoral cycle, or even a political career. Third, the necessary changes to limit climate change were substantial, and efforts within a single nation, while potentially costly and certainly disruptive, were going to be inadequate without extensive international cooperation. It is axiomatic that organizers must convince potential recruits that a particular situation is urgent and changeable and that their efforts could matter. In the case of climate change, all three criteria are particularly difficult: Urgency is masked, and the long time frame of both environmental change and social remedy can undermine a sense of urgency. That a global movement has emerged and recently gained momentum provides us with a chance to think through what organizers did in this case that mattered.

Effective social movements are opportunistic, inclusive, and enduring (*134*), even as marked moments of action and narrower campaigns can capture public attention. Opportunistic means that organizers need to constantly assess and reassess the political context and available resources, developing the flexibility to tailor claims and tactics to the needs of the moment (*135*, *136*). Scientists, recruited by organizers and in their own organizations, can play critical roles in all these issues.

Because of the nature of their work, scientific specialists are positioned in frontline observation posts for a range of social problems and, sometimes, in a position to affect policy by withdrawing their cooperation. For instance, the Union for Concerned Scientists provided elaborate explanations for the efforts of antinuclear activists when they staged a demonstration or civil disobedience action (*137*). Scientists can thus provide epistemological and political support for activists, extending the space for discussion in public fora, augmenting the movement's reach and legitimacy, and suggesting alternative policies. There are various prominent examples of scientists providing support for climate activists. Michael Oppenheimer, a physicist that was among the first scientists to push for climate change action, worked with philanthropic organizations to fund activists and scientists from the Global South to attend United Nations conferences on climate.

In 2007, author and scholar Bill McKibben cofounded 350.org while working with college students at Middlebury College. The group took advantage of digital technologies to coordinate national days of action around climate change, starting with the Step It Up day of action in 2007 (*138*). The group focused its energies on campaigns that encouraged colleges and universities to divest their holdings in fossil fuels and challenge the expansion of fossil fuel infrastructure and mass mobilizations in the form of large-scale demonstrations that involved events coordinated in multiple locations across the United States and around the world.

Since its founding, 350.org has become a professional environmental group with vast international reach. The trajectory of the group laid the groundwork for youth-led activism around climate change. Young people have initiated and animated a range of campaigns that emphasized their stake in the climate issue. In 2015, for example, 21 young people filed a federal lawsuit against the United States for failing to protect their future by limiting climate change. The case provided a venue for claims-making, public education, and scientific education. One of the scientists who gave testimony

during that first Senate hearing on climate change in 1988, James Hansen, who studied climate change as a scientist at NASA's Goddard Institute for Space Studies, served as a resource who informed the legal case, and one of the named plaintiffs was his granddaughter. This case is part of a global push by youth climate activists to attract attention to the climate crisis and the ways that governments are not responding adequately to the science of climate change (*139*).

Beyond filing court cases, young people continue to work at the forefront of the climate movement, both as individuals and in organizations. The Sunrise Movement grew out of a campus-based campaign at Wesleyan University, with help from established environmental groups. Since its inception, Sunrise activists have engaged in electoral campaigns to support progressive Democrats, linking their claims on climate change to economic restructuring, and later, came to engage in demonstrations and civil disobedience efforts. Even more visibly, Greta Thunberg, a Swedish teen inspired by gun safety activism after the Parkland School shooting, began a personal school strike for climate change in 2018 that has grown into a global movement that was fueled by frustration that governments were not listening to the science and lubricated by the digital affordances of social media (*140*).

Although scientists and activists have worked to bring about climate action, efforts have been insufficient to address the urgency of the problem (*141*–*143*). As the climate continues warm, there have been numerous calls for scientists to join the struggle as activists (*143*). Greta Thunberg became a global icon and inspired a global movement that has pushed for policymakers to follow science in the mainstream media, in collective action, and in front of international political bodies with the message: Listen to scientists (*139*).

Civic science and transparency

Listening to science is not possible when science is censored, kept secret, or inaccessible to those who stand to benefit from it. Democratizing science requires accessible and transparent data. Data justice activists often focus on data harms, including discriminatory actions such as using credit scores and neighborhood racial characteristics to deny loans, mortgages, or the ability to purchase homes through redlining (*144*). Data justice also counters political surveillance to control opposition political movements, carry out voter suppression, and enforce immigration status (*144*, *145*). Data justice activism also seeks restorative justice, as with Margaret Burnham's Civil Rights and Restorative Justice Project at Northeastern University, to categorize harms resulting from both civilian and law enforcement misconduct and violence during the civil rights movement, which included building a database of crimes and murders against activists.

The advocacy groups mentioned above are often grassroots activists dealing with localized contamination threats. They often are faced with the problem of inadequate official data or even total data secrecy, but there is another category of environmental and science advocacy groups that provide data for the general public. We provide some examples of organizations that have recently pioneered data justice and transparency actions. Collectively, these efforts demonstrate the diversity of ways in which scientists can draw on their distinct skills and coordinate action that forward broader struggles.

The Environmental Data and Governance Initiative (EDGI) is a North American network that includes over 150 members from more than 30 different academic institutions and many unaffiliated people. EDGI was formed in the first weeks after the 2016 U.S. elections to preserve federal environmental data, systematically document threats to science and regulation at the EPA and other agencies, and provide models of democratic environmental governance for the future. Its founders were prompted by the legacy of the George W. Bush administration (2001–2009) and the Canadian government under Stephen Harper (2006–2015), both of which had erased environmental data to effect deregulation, to undermine environmental policy and agencies, and to increase doubt and uncertainty on environmental issues such as climate change. EDGI held "Data Rescue" events, built open-source tools for grassroots web-archiving critical scientific research, conducted interviews with current and former federal agency employees to document attacks science, and tracked how EPA enforces federal statutes.

Toxic Docs has its origins in the 2005 acquisition of documents on polyvinyl chloride that involved public health historians Gerald Markowitz and David Rosner. Toxic Docs, which works extensively with EDGI, administers a repository of 30 million documents that come from corporations via FOIA requests and the discovery phase of class-action lawsuits on benzene, printed circuit boards, lead, polyvinyl chloride, silica, dioxin, and asbestos (*146*).

Many environmental groups, especially those dealing with environmental health, have dedicated energy to developing databases of material that is hard to obtain or hard to use even if attainable. The Endocrine Disruption Exchange (TEDX), a now-defunct organization founded by Theo Colborn, one of the greatest pioneers in environmental health, put together an extensive database of endocrine-disrupting compounds. The Environmental Working Group has several major databases on water quality. The PFAS Project Lab at Northeastern University's Social Science Environmental Health Research Institute has a large PFAS Contamination Site Tracker that shows the extensive contamination by this class of chemicals, an interactive map showing known and suspected contamination sites and state regulations, and the PFAS Tox Database (started as a TEDX project), which offers extensive information on PFAS toxicology research. Science networks and organizations have invested energies and resources in enabling scientist public engagement and advocacy. The UCS documents attacks on science and drafts policy language that is informing scientific integrity policies (*147*–*150*). Collectively, these efforts enable the continuity of research that can inform policy-making, advocacy, policy, and litigation.

Scientist public engagement and use of research evidence

The production of research evidence can contribute to organized efforts to exert science policy influence. Decision-makers can use peer-reviewed research for the validation of perspectives on issues that are not widely accepted (*151*). However, the existence of academic research is not a sufficient condition for evidence-based policy change (*152*, *153*) motivating the need for scientists to engage in the policy-making process through advocacy and science communication. Research can inform policy through a diversity of pathways (*154*), such as through relationships with policymakers and partnerships with practitioners to communicate and translate research and ideas into policies (*155*).

Existing studies on the use of research evidence propose a robust framework consisting of factors that can shape this phenomenon. These factors include the extent to which research is easily accessible; whether research users view producers as biased, partisan, and credible; the relevance of existing research to the issue in question; the nature and strength of the relationship among research users and producers; the involvement and interest that research users have in research production; researchers' knowledge of policy-making; the use of storytelling and other communication techniques that appeal to research users; the clarity and brevity of the research presentation; the timing and timeliness of the evidence; and the kinds of indicators used (*156*).

Policy stakeholders are more likely to embrace the use of research evidence when it is responsive to their needs, aligned with individual customs and institutional procedures shaping decision-making, and sourced through trusted partners (*157*, *158*). Research evidence, however, is not inherently aligned with efforts to use science to address inequality and achieve social change. Studies document the multiple ways in which research evidence has aided the development of policies that perpetuate racial inequalities and legitimize racial hierarchies (*159*). Research evidence can be a powerful tool, that is, a tool used to compel others to act. However, the deployment of research evidence as a tool can aid anti-oppressive mobilization and backlash against such emancipatory agency.

There is much work to be done to ensure that scientific engagement and advocacy happen in ways that are beneficial to society. Scientists can seize politically opportune moments to expand the benefit of science outwards in a concrete way. Three promising directions are noted below.

First, there are numerous outlets where scientists and science advocates can engage with the general public. Programs such as AAAS SciLine (www.sciline.org/scientists/) connect scientists with journalists and can help broker connections, but more broadly scientific organizations and scientists should also look at these forms of public engagement as a key role and responsibility of being a scientist. In an age of rampant dis- and misinformation, science can also play a critical role in countering incorrect narratives by strengthening relationships with media outlets and sharing expertise with those who play mediators between scientists and the public. There are numerous paths that can help increase the visibility of scientific work: OpEds, guest columns, serving as expert advisors to civil society organizations, and becoming involved in government advisory groups. Science has long been held as apolitical when this is simply not the case, especially in the critical political moment that we are in. Scientists in public forums must have an opinion and take a stance to help guide critical conversations on topics such as climate change, women's health rights, and societal approaches to addressing the COVID-19 pandemic.

Second, scientists and scientific institutions can serve as stronger advocates by networking and building relationships of trust with policy-makers at local, state, and federal levels of government. There are many opportunities to do so, such as providing congressional testimony, and commenting on regulatory proposals and requests for information from the federal government [see, for instance, (*160*–*163*)]. Developing the aptitude and proficiency for science professionals to inform and shape policy and understanding the most impactful routes for doing so can greatly increase the ability of science to make a difference. Scientists historically have not received training that supports policy outputs [e.g., (*164*)]. By advocating for the usability of research and challenging the sole valuation of the peer review paradigm, scientists can insist on the worth of their work in public forms that can better serve society and make stronger connections with organizations that could benefit from expert opinions.

A key area that requires further exploration in this arena is the visible practice of protest through movement and coordination. This tactic can be a critical piece of demonstrating discontent with government practices that deny the role and practice of science. While visible protest movements (from March for Science to March for Women) help bring attention to the problematic rhetoric prevalent during the last half-decade, activists have called for greater urgency and new strategies for forefronting science. These strategies are needed to ensure that despite movement in a "science positive" direction (e.g., reestablishment of federal scientific advisory councils), policy failures are addressed in a way that activates and energizes scientists and others to become involved.

Last, to do meaningful public science and advocacy work, scientists must transform systems that have upheld (and in some cases, encouraged) problematic and extractive behavior. Public engagement in science and as a strategy for making closer connections between science, scientists, and communities has recently seen greater attention (*165*). However, science has a long history of doing community engagement in ways that are inequitable and extractive [see, for instance, (*166*)]: helicoptering into communities; not establishing clear and fair guidelines for data ownership, management, and use; and establishing relationships for the sake of checking a box on a grant application, to name a few examples. Science engagement with communities can come in many different forms. There are great models that abound, such as ways to make science communication more inclusive and representative (e.g., Metcalf Institute's Inclusive Science Communication and Ciencia Puerto Rico; www.cienciapr.org/) and building relationships between scientists and communities through community science projects, such as what the Thriving Earth Exchange (https://thrivingearthexchange.org/) at the American Geophysical Union has done. Community-centered practices and modes of engagement are well documented. Still, the time is right for scientists to push for better models of interaction, as the Biden administration has shown increased interest in efforts to address equity in science and technology. Even when there are no clear partnership opportunities, scientists can do the preparatory work of building relationships with community leaders and others so that relationships can be formed around mutual trust. Engaging in science communication and dissemination and building relationships with communities are important pathways for supporting health and environmental justice struggles.

CONCLUSION

This article synthesizes research suggesting how science-related organizations can generate politically meaningful advocacy that democratizes science, promotes intergroup equity, and influences public policy. We argue that an intersectional organizing approach enhances social movements' abilities to cope with these and related challenges, in part by wielding diversity as a political resource. Such an approach prioritizes the experiences and concerns of marginalized communities, supporting their leadership, seeking

coordination among professional and lay allies without suppressing difference and disagreement, and strengthening the autonomous organization of marginalized groups (*20*, *38*, *42*). While effective science mobilization builds solidarity among scientists and community groups (*92*), to maximize impact, those networks and coalitions must engage communities as co-producers of knowledge and ensure more substantive community representation in research outputs and budgets, for example, by supporting and remunerating the work of community bridge-builders.

This article reviews literature from several fields, including sociology, science and technology studies, environmental politics, political science, public health, medical history, and epistemology, among others. In doing so, we seek to broaden the theoretical frameworks that inform the study and practice of science advocacy and to mirror the diversity of scholars and areas of inquiry that examine the emergence and influence of science activism. For instance, we consider how existing research on the broad topic of social movements informs science advocacy specifically. We expect that contextualizing research on science advocacy in relation to broader bodies of literature will enable deeper interdisciplinary engagement and intellectual advancement of the study and practice of science advocacy. Given this approach, the review is necessarily selective and is not inclusive of all research on science advocacy and relevant topics. We aimed to cite works that are representative of larger bodies of work. In our selectivity, we also had a bias for including the research of junior scholars, scholars of color, and more recent work. We recognize existing efforts, particularly within the Society for Social Studies of Science, to diversify scholarship beyond the United States. The disproportionate representation of scholarship from the Global North is a limitation of this article.

Future work that carries on efforts to synthesize insights from the study of intersectionality, social movements, and structural inequality in science and technology studies holds the potential to advance theory and praxis focused on enacting justice within and through the sciences. Further research is needed to deepen understanding of how science mobilization emerges and exerts political impact. Existing research is largely focused on specific campaigns, organizations, or issue areas. These studies provide strong examples of scientist engagement and rich debates on the politics and consequences of scientific expertise. However, data limitations hamper research beyond large organizations and across scientist networks (*167*). Research on these matters must cope with the challenges of studying a population that is hard to identify, a form of mobilization that is largely episodic and often operates under the radar (*7*). For example, efforts within the UCS to study the intimidation of federal scientists relied on Freedom of Information Act requests to identify their population (*168*).

Another important line of future inquiry should shed light on generational dynamics and the implications of the differential politicization of early career scholars politicized during the past decade and who come to research with different understandings of how science and politics intersect. We also need to be studying scientific organizations, central nodes in the formal and informal networks mobilizing and building unity among scientists and science advocates (*7*, *9*, *10*). We know from social movement research that mobilization gains strength through investments in leadership development, youth and community mobilization, and seizing the opportunity to turn protest participants and network supporters into organizers who move others to action. Similar needs and challenges apply to science and science advocacy, in all their varieties.

Science advocates seek to influence policy-making through different methods, including protest, advocacy, data justice work, engagement with news media outlets, and social media outreach, among other forms of mobilization. Although there is debate around the relative effectiveness of each of these different methods, movements can adopt a diverse tactical repertoire that does not rely exclusively on one method for achieving policy change or continuity in cases in which activists defend existing policies. Tactical diversity can improve movement vitality (the strength of a movement) by broadening the scope of their actions, venues, support, and strategies (*169*). Different tactics appeal to different participants and audiences. Implementing multiple tactics simultaneously makes them more likely to be endorsed (*169*).

Embracing diversity should not be limited to a diversity of tactics. Movements can use identity diversity as a political resource (*170*). Diversity enhances movement analyses of the context in which they operate in ways that inform their tactical repertoire and allows them to innovate. Movements that embrace identity diversity can expand the spectrum of groups from which they draw support. Diverse movements can also assert that they represent a broader array of groups than movements lacking diversity, thus gaining greater standing in the public eye and among policymakers. Movements that promote science advocacy have a history of excluding people from marginalized groups. Science institutions and organizations can resort to intersectional solidarity to transform their entities and fields in ways that subvert exclusion and marginalization in the sciences. Younger scholars and scientists, politicized by Black Lives Matter, anti-Trump activism, and climate change, among other emerging movements, offer a path for changing how politics operates within the sciences, acknowledging that some fields are and have been more inclusive and open to recognizing their own hidden politics than other fields. The 2020 Black Lives Matter uprising is indicative of the spillover that justice-oriented activism has on science mobilization, potentially expanding and changing what we understand science advocacy to be. Movements that subvert histories of exclusion and domination within their own organizations are effective vehicles of social change for marginalized groups (*171*, *172*).

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