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Improving the agri-food biotechnology conversation: bridging science communication with science and technology studies

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Abstract

At a time when agri-food biotechnologies are receiving a surge of investment, innovation, and public interest in the United States, it is common to hear both supporters and critics call for open and inclusive dialogue on the topic. Social scientists have a potentially important role to play in these discursive engagements, but the legacy of the intractable genetically modified (GM) food debate calls for some reflection regarding the best ways to shape the norms of that conversation. This commentary argues that agri-food scholars interested in promoting a more constructive agri-food biotechnology discussion could do so by blending key insights, as well as guarding against key shortcomings, from the fields of science communication and science and technology studies (STS). Science communication's collaborative and translational approach to the public understanding of science has proven pragmatically valuable to scientists in academia, government, and private industry, but it has too often remained wedded to deficit model approaches and struggled to explore deeper questions of public values and corporate power. STS's critical approach has highlighted the need for multi-stakeholder power-sharing and the integration of diverse knowledge systems into public engagement, but it has done little to grapple with the prevalence of misinformation in movements against GM foods and other agri-food biotechnologies. Ultimately, a better agri-food biotechnology conversation will require a strong foundation in scientific literacy as well as conceptual grounding in the social studies of science. The paper concludes by describing how, with attention to the structure, content, and style of public engagement in the agri-food biotechnology debates, social scientists can play a productive conversational role across a variety of academic, institutional, community-level, and mediated contexts.

Keywords Science communication · Science and technology studies · Biotechnology · Genetically modified food · Food systems · Public engagement

Abbreviations

CCDH	Center for Countering Digital Hate
GM	genetically modified
STS	science and technology studies
AAAS	American association for the advancement of science

Introduction

The topic of agri-food biotechnology continues to engender both excitement and contestation across the global food system. For decades, the enterprise has been championed by advocates as a powerful force for the promotion of environmental sustainability, increased agricultural productivity, enhanced nutrition, and food security; at the same time, critics have raised concerns on a variety of fronts, including questions about its ecological effects, health and safety impacts, and implications for food system power and corporate concentration (Lang 2016). In the United States, specifically, a variety of genetically modified (GM) foods created through the alteration of plant DNA have been grown, regulated, and sold since the 1990s. More recently, innovations in gene editing, synthetic biology, nanotechnology, and related techniques have ushered in a new generation of

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novel plant and animal foods, existing today at varied stages of development, regulation, and commercialization (Bain et al. 2020).

Public interest in agri-food biotechnology has ebbed and flowed over the course of time, with the current moment appearing to represent another high point. Incumbent actors in agri-food biotechnology – including multinational agricultural and life sciences corporations, academic researchers, and government agencies – have been joined recently by players from the world of Silicon Valley and other geographically-disperse technology hubs, bringing a rush of new entrepreneurs, investors, scientists, communications professionals, and public attention to the field (Fairbairn et al. 2022). From the use of genetic engineering and precision fermentation in the production of plant-based meats or animal-free dairy products, to the gene editing of both crops and animals using tools such as CRISPR-CAS9, to the creation of cultivated meat products through cell-culturing technology, a diverse set of agri-food biotechnology processes and products are taking shape (AgFunder 2022). In the US as elsewhere, these developments give rise to a variety of new questions about ideal forms of regulation, citizen engagement, financing, and consumer choice, calling for serious public discussion about the best pathways forward (Bain et al. 2020; Irwin 2008; Montenegro de Wit 2022).

The fundamental aim of this commentary is to explore what scholars at the intersection of science and technology studies (STS), science communication, and critical agri-food studies can do to promote constructive conversations about the scientific nature and societal implications of emerging agri-food biotechnology. The work begins from the normative position that, for those who want to promote a healthy, equitable, and sustainable food system, improved discussion on divisive food system issues should be considered a desirable goal. Better discussions on these topics can improve shared understanding, an intellectually valuable objective in itself, while also providing instrumental value, opening up possibilities for collaborative compromises that might advance shared food system aspirations. This is not to say that achieving outright consensus about the "facts" of agri-food biotechnology's limits or potential is the objective – instead, following Latour (2004), conversation would ideally help society move from a limited focus on "matters of fact" toward "matters of concern," by offering participants arenas in which to gather and explore "highly complex, historically situated, richly diverse" socio-technical issues (p. 237).

Given the contemporary surge of investment, innovation, and public interest, it is common to hear both supporters and critics of agri-food biotechnology call for open, public, inclusive dialogue on the topic (Center for Food Integrity 2021; IPES-Food 2022). As Chilvers (2013) has outlined, social scientists can and have had an influence on the public's engagement with a variety of science and technology topics, through a combination of studying, practicing, orchestrating, and coordinating across diverse assemblages of societal actors. In the context of emerging agri-food biotechnology, social scientists have a potentially important role to play, not only as researchers, but also as facilitators, teachers, citizens, members of institutions and organizations, and resources for journalists and policymakers. Writing as a critical social scientist focused on food systems and communication, the question I pose in this discussion paper is, how can our intellectual community best prepare for the task of bolstering the quality of future agri-food biotechnology conversations? The fundamental argument outlined in the pages ahead is that, in order to optimally fulfill this role, agri-food scholars need to address a bifurcation in the fields of science communication and STS, such that science communication's commitment to an empirically grounded communication of scientific information becomes wedded to rather than pitted against STS's commitment to reflexive and dialogic processes of public engagement. This conclusion emerges from long-standing frustration with the intractable character of many agri-food biotechnology debates (Lang 2016), as well as from scholarly observation of both the strengths and weaknesses of science communication and STS approaches. To return to Latour (2004) and his influential work pondering whether critique had run out of steam, I call for an approach that takes a stubbornly realist attitude in addressing matters of concern, one that resists the downsides of scientific positivism, but also remains on guard against the potential to indulge anti-empirical bad faith actors in the name of epistemological diversity.

Notably, I come to this work with an ambivalent relationship to agri-food biotechnology, believing that some of these tools could play a productive role in grappling with the varied challenges of the contemporary food system, but also retaining skepticism about the hype that often accompanies their introduction (Broad 2019). My approach is informed by my training as a mixed-methods communication researcher in the US, educated and practiced in both empirical and critical approaches, including perspectives from both science communication and STS. Topically, my scholarship has focused on a variety of food system issues, including movements for food justice and, more recently, debates about agri-food tech innovation. Over the course of the last 15 years, I have taken on varied roles in these explorations – student, teacher, scholar, collaborative researcher, advocate, and engaged community member among them – and this commentary will therefore draw from a mix of academic and personal insights gained from these positions. With that in mind, the next section of this work considers the science communication and STS approaches to public

engagement with agri-food biotechnology, paying specific attention to the history and legacy of the GM food debate in the US. It follows from there by drawing on an interdisciplinary set of resources that explore how to promote constructive conversation on divisive issues, reflecting on how social scientists of agri-food biotechnology might achieve this goal, whether in our classrooms, academic institutions, in media, or our communities at large.

Science communication, STS, and the GM food debates

Scholarship in science communication and STS, while sometimes overlapping, has generally taken two different stances when considering scholarly intervention in the public's engagement with science and technology. On one side, science communication is generally grounded in a "public understanding of science" perspective, characterized by efforts to use varied forms of science education to improve the public's scientific literacy and counter misinformation in the public sphere (Bronson 2014). It is a translational approach that has long been pragmatically valuable to scientists in academia, government, and private industry, helping to create platforms for expert-public engagement and information dissemination (National Academies 2017).

Traditional science communication has long been critiqued for a reliance on the "deficit model," wherein the science of an important question is pre-determined to be settled, immutable, and clear to experts, with the communicative outreach that takes shape focused mostly on explaining the facts to the public. Yet, even within the science communication field itself, this perspective has been criticized as deeply flawed and inefficacious, on a host of accounts – the deficit model tends to deny the nuances and complexity of science; depends on fallible one-size-fits-all communication strategies; and does little to consider how different value systems might lead different publics to different conclusions about ideal futures and appropriate next steps. From this perspective, the general consensus is that an effective public engagement strategy should not merely be focused on filling gaps in assumed public ignorance. Instead, contemporary science communication explores how to build scientific and institutional trust, emphasizing the importance of transparency, shared values, and ongoing dialogue with diverse publics (Ahteensu 2012; Lang et al. 2003; National Academies 2017).

Scholars in STS have taken a decidedly different tack, focusing primarily on the social and political contexts that shape the construction and communication of scientific "facts," and often directly calling into question the translational approach of science communication (Bronson 2014). Many STS scholars have been doubtful that mainstream science communication has truly moved beyond the deficit model – while it may be true that the field is more deliberate in its efforts to engage public stakeholders and communicate shared values, they have not taken the next step to question the construction of scientific power and expertise itself. What has emerged from this exercise, STS scholars argue, is simply a revamped version of the original deficit model, intended to lend greater legitimacy and persuasive power to expert-led efforts rather than promote actual collaboration or, more importantly, basic reflexivity regarding whether a particular scientific innovation is worth pursuing at all (Wynne 2006; Marris 2015). Offering an alternative vision of risk and science communication, Irwin (2008) called for a move beyond both the deficit model (first-order thinking) and expert-led trust-building approach (second-order thinking), advocating for "third-order thinking" that places science-public issues in a wider context, invites multiple stakeholders, and is open to contested problem definitions.

A closer look at debates around earlier generations of GM foods in the United States offers insight into the strengths and limits of both approaches to communication and agri-food biotechnology. After decades of wrangling on the issue, today, the overall tenor of the GM debate in the US is characterized by some combination of confusion, dissatisfaction, or exhaustion, regardless of one's particular stance on the technology (Evanega et al. 2022; Fernbach 2019; Lang 2016). As one notable piece of evidence, a 2014 survey from the Pew Research Center and the American Association for the Advancement of Science (AAAS) explored both public and scientific expert opinions on a variety of issues related to science and society. The single largest expert-public "gap" came on the topic of GM foods – when asked if genetically modified foods were "safe to eat," only 37% of US adults said yes, compared with 88% of AAAS scientists (Pew Research Center 2015).

In response to such gaps, the work of science communication scholars and their allies in industry, government, and scientific research generally reflected the "public understanding of science" perspective, focused on addressing barriers to public understanding about GM food's safety. Ultimately, the key lesson learned by science communication professionals was that they failed to clearly communicate the nature and implications of GM foods to the public, that they underestimated the collective strength of the anti-GM coalition in questioning the motives and trustworthiness of GM innovators, and that they had not done nearly enough to anticipate a rush of pseudoscientific misinformation that flooded the public communication environment and drowned out the voices of more restrained scientific experts. Looking ahead, they concluded, future agri-food biotechnology communication strategies would have to

be more pro-active, more transparent, more dialogic, and more willing to share stories about the potential value these tools could offer to make the world a better place (Center for Food Integrity 2021; Landrum et al. 2018; Lynas 2018).

The takeaway in much of the STS literature was quite different, coalescing around what might be termed a "political ecological critique." Here, considerations of public concern regarding the public health and environmental risks of GM foods were combined with a focus on the social, political, and economic conditions that bred distrust of GM technology, as well as the industries that advanced it, in the years preceding and during its roll-out. STS scholars criticized early 21st century public engagements on the topic of GM food as too narrow in focus and unidirectional in their communication approach. Largely organized by biotechnology supporters, these convenings were grounded in deficit-model thinking that assumed information provision about the safety of GM food would be enough to allay what the conveners believed to be irrational public concern (Wynne 2006). However, in the eyes of many STS critics and allies in diverse activist communities, public concern was quite a reasonable response to the actions of the untrustworthy confluence of "Big Food" and biotechnology, reinforced by numerous examples of unethical corporate behavior, as well as a questionable regulatory approval process that lacked transparency and never truly demonstrated the long-term public health or environmental safety of GM technology at all (Krimsky 2019).

In the years since, a number of scholars in STS and overlapping critical agri-food studies have been quick to point out that many of the concerns they expressed from the outset, but were often dismissed by agri-food biotechnology supporters as irrelevant, have been borne out by the GM food experience. GM food advocates have consistently over-promised and underdelivered, as well as obfuscated the novelty of emerging agri-food technologies as compared to traditional domestication and plant breeding (Mueller and Flachs 2022). Meanwhile, critics argue, many of the worst tendencies of industrial agriculture – including an over-reliance on chemical herbicides, the destruction of agricultural biodiversity, increased consolidation in corporate power, and the undermining of local agricultural economies and traditional agroecological knowledge systems – have come to fruition (Landrigan and Benbrook 2015; Stone and Glover 2017). For many, GM foods simply reinforced or left unaltered systemic injustices that remain embedded within the global capitalist food system – including the legacy of failed techno-solutionist promises, industry capture of regulatory processes, environmental degradation, colonial exploitation, economic inequality, animal cruelty, and diet-related disease among them – validating their political ecological critique along the way (McMichael 2009).

And yet, as new generations of agri-food biotechnology emerge, industry science communicators have done little to reflect on this socio-historical context, remaining consumed instead by what Marris (2015) termed "synbiophobia-phobia," or fear of the public's fear of synthetic biology. Further, as new entrants from Silicon Valley enter the agri-food tech arena, they present a style of "solutionist" thinking (Morozov 2013) in which they propose monumental and narrow-minded technological solutions to complex global problems. In so doing, they project a vision of a public "whose sole role is to accept and consume new technologies rather than a citizenry who is invited to meaningfully engage with their development or governance" (Biltekoff and Guthman 2022). In other words, at a time of emerging agri-food biotechnology innovation, STS's political ecological critique suggests that the actions of scientists and industry are setting us up for yet another intractable food fight.

The misinformation problem

This political ecological perspective on the agri-food biotechnology industry's incomplete risk assessment and flawed public engagement approaches was central to shaping my perspective on the GM debates. And while I still believe it has serious merit, over time, my ongoing connection to the science communication field suggested to me it didn't quite tell the full story about how the GM food debate went off the rails, nor what we might be able to do to get agri-food biotechnology discussions back on track. A turning point for me began during the 2012 California Proposition 37 campaign, which asked voters whether most GM foods should be labeled as such. The initiative was narrowly defeated, thanks in large part to a well-funded opposition campaign from food and biotechnology industry interests, led by the Monsanto Company, that largely emphasized economic costs to consumers. The lead funder in support of the labeling initiative was Joseph Mercola's Mercola.com Health Resources LLC, whose public-facing message, put forth under the banner of the Yes on 37 Right to Know campaign (Voters Edge 2012), veered away from a firm political ecological argument to emphasize claims about GM food's health dangers. In one ad, snapshots of historical corporate public relations campaigns that touted the benign health risks of cigarettes, DDT, and agent orange were highlighted before a not-so-subtle comparison to the potential dangers of genetically engineered food (CA Right To Know 2012). The campaign also coincided with the release of an academic study, conducted by the French molecular biologist Gilles-Eric Séralini, that purported to show that genetically modified maize, along with its companion commercial herbicide, were toxic and caused tumor growth in rats. The study was

soundly criticized for methodological and ethical errors and was eventually retracted by the journal, although published elsewhere without additional peer review, and promoted throughout the Prop 37 effort (Science Media Centre 2014).

Despite other legitimate critiques of GM technology, up to that point and in the years since, rigorous scientific investigation has continued to find no reliable evidence of the types of negative individual health impacts of GM foods that were amplified in the Proposition 37 campaign and remain widely espoused by many anti-GM activists (National Academies 2016). And yet, public opinion research shows that the vast majority of people who say they avoid GM foods in the US do so not on account of concerns related to their political ecological implications, but rather based in unease about the impact of GM foods on their individual health. A 2018 survey from the International Food Information Council (2018) found that, among those who say they avoid bioengineered foods, 85% cited human health concerns as a reason for doing so, followed distantly by environmental concerns at 43%. Other polling from the Pew Research Center (2016) found that a majority of US respondents did not believe that most scientists agree GM foods are safe to eat. In that survey, 40% of total respondents indicated that GM foods are worse for health than non-GM foods, including 75% of those who say they care "a great deal" about the issue; more than half of those concerned about GM food impacts on health believe that risk to be high. In another recent study in the US, researchers found that high levels of concern and extremity of opposition to GM foods were correlated with high levels of self-assessed knowledge on the topic, but each of those variables was inversely correlated with test scores of objective knowledge about science and genetics. Put bluntly: "Extreme opponents know the least, but think they know the most" (Fernbach 2019, p. 251).

A host of journalist, activists, and researchers have closely catalogued the preponderance of health misinformation put forth by certain elements of the anti-GM advocacy community (Saletan 2015). In mass protests and online, "Frankenfood" memes permeated anti-GM messaging (Clancy and Clancy 2016), while abstention from GM foods became a central prong of wellness industry fad diets and "clean eating" influencer trends (Chrzan and Cargill 2022). Across these contexts, hyperbolic health claims have frequently been tied to broader political ecological concerns and corporate critiques, leading to situations in which GM health conspiracies are featured right alongside the work of legitimate critical agri-food scholars (see, for instance, the contributions to Shiva 2016). Lynas et al. (2022) found that approximately 10% of mainstream news media coverage of agricultural biotechnology included negative misinformation, mostly about health and safety impacts. A recent study by Ryan et al. (2020) found that much of the most visible and widely shared online coverage of GM food issues originated from monetized alternative health and pro-conspiracy websites, including a mix of misinformation (inaccurate or incomplete) and disinformation (intentionally misleading).

Other recent analysis has noted clear links between the anti-GM movement and the anti-vaccination movement, both before and during the Covid-19 pandemic (Bredderman 2021; Hoffman et al. 2019). As one operative example, Joseph Mercola, the long-time funder of anti-GM advocacy made wealthy through the sale of unproven dietary supplements, was identified as the single biggest spreader of Covid-19 and vaccine-related disinformation by the Center for Countering Digital Hate (CCDH). Indeed, several of those identified as part of CCDH's "Disinformation Dozen," responsible for a significant proportion of online anti-vaccine content during the Covid-19 vaccination rollout, have a history of engagement in health-focused anti-GM advocacy (Center for Countering Digital Hate 2021).

Yet, within the STS and critical agri-food studies communities, it is the political ecological critique that is still seen as the dominant, if not only, reason for public concerns about GM foods. Personally, I have lost track of the number of times I have heard other scholars insist that opposition to GM food is not "really" about health concerns, but rather about the political ecological issues that tend to concern those academics the most. If mentioned at all in this arena of scholarship, issues of public (mis)understanding and misinformation are often treated as a quirk of big tent anti-GM activism, while activists committed to the political ecological critique have shown a willingness to either ignore or actively leverage health-related anxieties to amplify their movement's voice (Yearley 2008). To be clear, it is very likely the case that when many people express concern about the individual health implications of GM foods, they are not considering that issue in isolation from other concerns about environmental health, naturalness, or the overall trustworthiness of the food and biotechnology industries (Scott et al. 2018). Even still, the evidence from science communication suggests that health misinformation is an important dynamic within the agri-food biotechnology debates, such that critical agri-food and STS scholars should be doing much more to consider its manifestations and implications.

There are several potential explanations for this uneven scholarly attention. Notably, some scholars dispute or deny the health misinformation argument outright, insisting that a focus on that topic is actually industry propaganda intended to undermine political ecological critiques (Nestle 2017). Here, again, the parallel between anti-GM and anti-vaccination movements is notable. As Minkoff-Zern and Welsh (2017) asserted prior to the Covid-19 pandemic, "the fears of 'anti-vaxxers' are based on a widely discredited theory.

And, vaccines provide widespread and indisputable public benefits," whereas "in the case of GM crop, the concerns are less about safety and more about a broader set of issues—namely political and economic ones which are yet to be addressed by GM crop proponents" (p. 387). For reasons outlined above, I find this claim unconvincing.

Another reason for this state of affairs may be the selection of case studies by scholars in STS and critical agri-food studies, who may tend to gravitate toward cataloging movements that reflect their own political ecological concerns. For instance, Gupta's (2018) case study of anti-GM food activism on the Big Island of Hawai'i argued that resistance to GM foods can be seen as "representative of a wider set of struggles around choice, sovereignty, agrarian reform and resistance to neoliberalism," able to garner support across disparate groups by articulating "a vision of food sovereignty and local control over their agri-food system that challenges corporatism and industrial agriculture" (p. 190). Bronson's (2014) case study of farmer resistance to GM agriculture in Western Canada similarly argued that farmers' concerns did not fit within the epistemic space that the deficit model affords, given that their problems were not with biotechnology per se, but rather "centre upon the social and political context of the science (i.e., the constitution of facts used in regulation)" (p. 529).

It is also possible that STS-oriented investigations of misinformation in the anti-GM debate have been omitted by scholars who struggled to incorporate them within their conceptual framework. I speak from experience on this count – while conducting fieldwork for my dissertation and book project (Broad 2016), I spent time with youth-focused food justice organizations, right around the same time as the California Proposition 37 campaign. During this experience, I often heard unfounded statements about the health impacts of GM foods spoken by youth participants, community partners, and adult organizational leaders. At the time, I struggled to consider how an STS-informed perspective that valued non-expert forms of knowledge could reconcile these incongruities, so I made little mention of the topic in my writing and instead focused more heavily on the broader political ecological critique that was also present in their rhetoric. I regret that decision today, but at the time, lacked the analytical insight and, perhaps, courage to say otherwise.

Taken as a whole, the intractable GM food debates bring to light shortcomings in both science communication and STS. Scholars in science communication reflect back and wonder what they could do to more effectively explain the processes, products, risks, benefits, and cultural values of agri-food biotechnology to diverse publics, including those who may struggle to grasp complex scientific issues or fall victim to misinformation. As astutely noted by STS scholars, the downside to this public understanding of science perspective is its belief that consensus is an achievable or even desirable goal, and that debates about any particular technology can be explored without reflexive attention to the broader cultural and institutional power dynamics at the root of science-society interactions. From this perspective, dominant institutions wield science communication in order to pursue their interests, and the intractability that results is a product of the limits of the pervasive deficit model. Yet, in building an intellectual community around this epistemological critique, the intersection of STS and critical agri-food studies has overlooked important insights that do emerge from science communication scholarship. Not only has the prevalence and relevance of public knowledge gaps been underexplored, but the field has also made itself vulnerable to manipulation by bad-faith actors, those who exploit its embrace of epistemic diversity by promoting pseudoscience under the cover of political ecological critique. These developments once again bring to mind Latour (2004), who argued that the goal of critical inquiry into socio-technical systems was "never to get *away* from facts but *closer* to them, not fighting empiricism but, on the contrary, renewing empiricism" (p. 231).

Toward better agri-food biotechnology conversations

The remainder of this commentary offers reflections on how social scientists interested in agri-food biotechnology might help renew empirical deliberation on the topic, by blending the strengths of both science communication and STS perspectives, as well as drawing upon interdisciplinary scholarship on communication across difference. As noted, social scientists have a potentially productive role to play in advancing what Irwin (2008) deemed "third-order thinking" in risk and science communication, characterized by reflexivity, multi-stakeholder engagement, and civil contestation. If we want to avoid the errors of the earlier GM debates, we will need to actively create spaces for this type of conversation to take place – in our classrooms, academic institutions, in media, and across broader community and policy domains – a task that is easier said than done.

A wide body of literature across the fields of communication and media studies, intergroup contact and conflict-mediation, stakeholder engagement, and political philosophy can provide useful guidance on this topic. Taken as a whole, the literature suggests a suite of principles focused on the structures of participation, as well as the content and style of conversation, that social scientists could put into practice. As the journalist Amanda Ripley (2021) has summarized, the fundamental lesson for anyone who wants to cultivate healthy conversations amid conflict is to "complicate the

narrative early and often" (p. 246). Ultimately, the act of improving conversations and increasing complexity in high-conflict debates is not necessarily a means toward consensus, as individuals and communities do not simply surrender their beliefs or defect from one position to the opposite extreme. "Instead, they do something much more interesting: they become capable of comprehending that with which they *still* disagree" (Ripley 2021, p. 5).

From the perspective of structure, best practices consistently emphasize the importance of representative participation, equal status among participants, and balanced and transparent moderation (Pettigrew 1998; Rowe and Frewer 2000). As Táíwò (2022) put it, a constructive approach to politics requires a "focus on building and rebuilding rooms" (p. 12) that shape public discourse and action, from the rooms of governmental decision-making, to newsrooms, to academic conference rooms, as well as across the virtual rooms of our digital age. Rooms constructed in this vein should be grounded in accountability rather than conformity, featuring a diverse set of perspectives but also remaining reflexive about the privilege (and, quite often, non-representativeness) that comes with being in those particular rooms at all. Where possible, such engagements should also establish a clear set of agreed upon goals and intended outcomes, such that participants see value in devoting their time, and possibilities for collaboration rather than competition are able to emerge (Kliskey et al. 2021).

In the context of agri-food biotechnology, these structural insights call for pushing back against the long-held tendency in which advocates from industry and scientific research are the primary organizers and guests of honor in dialogues and convenings. As STS scholars have rightly pointed out, such a structure leads to inherent power imbalances that make it difficult for the open exchange of ideas, narrowing the agenda of potential issues to be investigated and preventing those from outside core networks of power to have any real influence on the processes and outcomes that take shape (Wynne 2006). If informed by this critical insight, the pragmatic orientation of science communication, characterized by its history of crafting actionable platforms and strategies for public engagement, could help turn value-oriented power-sharing commitments into practical change. In the words of Táíwò (2022), "Whether on a small scale or in a large institution, our orienting political goal is to *build things*, whether institutions, norms, or other tools (pp. 107–108).

Representative participation alone is not sufficient, however, to promote constructive intergroup dialogue, as both the content and style of conversation are central to productive interaction. Especially when involving disputes that are interwoven with aspects of identity, morality, and worldview (as agri-food biotechnology certainly is), it is vital to create an environment of sharing, respect, trust, and reflexivity, grounded in the integration of stakeholder knowledge with scientific expertise (Kliskey et al. 2021). As the conflict-mediation scholars Kugler and Coleman (2020) outlined, the best antidote to intractability is pushing for "integrative complexity," a cognitive and emotional state that is reached when individuals and groups are able to resist dichotomous, black and white thinking that ignores ambiguity, and instead recognize the possibility of multiple perspectives on an issue. Research across these interdisciplinary bodies of scholarship also emphasizes the importance of all participants having equitable access to and, ideally, understanding of information relevant to the issues under consideration (Rowe and Frewer 2000).

In terms of the implications for agri-food biotechnology conversations, one important step is to call on participants to articulate, as clearly as possible, how they define the meaning of abstract, value-laden concepts such as equity, justice, and sustainability. Across the agri-food biotechnology debates, key stakeholders often insist that they are working to promote these goals, but stakeholders bring with them contrasting understandings of history and divergent visions of ideal futures (Montenegro de Wit 2022; Broad and Biltekoff, 2022). An exercise that puts these definitions at the forefront is unlikely to lead to consensus, but it can offer some concrete guidelines for engagement, as well as further the possibility of shared understanding.

It is also key to ensure that all participants do have a working knowledge of the basic scientific issues being discussed; this is particularly the case given the diversity of contemporary innovations in agri-food biotechnology, which bring with them different scientific processes and different implications for public health, the environment, economics, and society (AgFunder 2022). As incomplete as the deficit model is, there are indeed situations in which it is relevant to address public knowledge gaps; as Ahteensuu (2012) argued, a primary task for improving public engagement with science is "to better distinguish between cases in which these type of explanations and assumptions are warranted and cases in which they do not hold" (p. 310). On the other side of the equation, if structural changes have ensured equal participation, devoted agri-food biotechnology advocates should no longer be able to gatekeep the types of content deemed relevant to the conversation. As STS and critical agri-food studies scholars have insisted, it is important that all stakeholders listen seriously to other ways of understanding and engaging with food and agricultural systems, those that emerge not only from traditional scientific food safety risk assessment domains, but also from anthropological and sociological perspectives, cultural knowledge, ethics, and lived experience.

The content of this information exchange is mostly irrelevant, however, if the style of engagement is hostile. Central to Ripley's (2021) framework for "complicating the narrative" is the need to "reduce the binary" between groups and to marginalize the "fire starters" who serve as "conflict entrepreneurs" by dividing the world cleanly into good-versus-bad. Research shows that constructive interaction across difference provides participants with opportunities to become friends, allowing for the creation of affective ties, learning about outgroups, and a reappraisal of one's ingroup that can lead to a less provincial view (Pettigrew 1998). Absent these friendly elements, intergroup interaction is actually likely to further entrench or exacerbate conflict, a reality often on display in our contemporary digital and social media environments. Indeed, Bail (2021) demonstrated how being exposed to opposing views on social media platforms – commonly referred to as breaking the "echo chamber" – tends to enhance polarization rather than defuse it, fueling extremism, muting moderates, and all together acting as a prism that distorts our sense of selves and each other. It takes active effort to become aware of and reflect on these distorting effects, and from there take steps that expose us to views that we find acceptable or reasonable, even if we don't agree with them outright, ideally with a friendly mindset.

Critical social scientists helping to convene conversations about agri-food biotechnology have an important role to play in shaping a collegial environment across online, in-person, and hybrid contexts. Agri-food scholars can work with and demand that journalists and communication professionals make a concerted effort to resist overly divisive norms, draw out a range of perspectives, and encourage civility alongside accountability. Conversations should be grounded in tough but fair questioning about the interests, worldviews, and empirical arguments of key stakeholders. As STS scholars have consistently pointed out, historical and ongoing inequity, perpetuated by the behaviors of powerful players in the corporate food regime, remains perhaps the greatest obstacle to opening up space for constructive dialogue between dominant powers and those who question the value of agri-food biotechnology (McMichael 2009). Encouraged to reflect on this state of affairs, agri-food biotechnology advocates should be pushed to abandon a stylistic tone that sees any and all opposition to their products as the uninformed musings of irrational "anti-science" activists, a move that could go a long way toward improving constructive engagement.

Meanwhile, even as it is important for agri-food biotechnology advocates to recognize the validity of multiple forms of scientific and cultural knowledge as part of food system debates, it is also important to heed the insights of science communication and guard against the threats of misinformation and disinformation. Expanding the realm of legitimate knowledge should not be seen as a relativist free-for-all that treats conspiratorial claims or outright pseudoscience as on par with rigorous scientific and social scientific research, valid historical and political economic analysis, or relevant cultural and philosophical reflection. It hardly makes for a friendly conversational environment when anyone who sees value in the possibilities of agri-food biotechnology is smeared as a corrupt industry shill (Zaruk 2017); in fact, this rhetorical approach actually serves to overshadow and undermine valuable political and economic critiques, as well as scares away potential allies and collaborators from scientific research and industry. Fundamentally, a renewed empiricism calls for differentiating across and exploring the connections between science, innovation, and food system policy. A better agri-food biotechnology conversation will require a strong foundation in scientific literacy as well as a conceptual grounding in the social studies of science – choosing one or the other is a recipe for intractability.

Conclusion

Debates about agri-food biotechnology have been ongoing for decades, but the current moment of food system innovation and contestation has attracted increased attention and, at times, intractable rancor. Interested parties from across the ideological spectrum lament the overall poor quality of conversation that accompanies these debates, but offer diverging interpretations regarding the causes of intractability. In the scholarly community, science communication researchers have tended to emphasize disconnects between expert knowledge and public understanding, while STS scholars have emphasized disconnects between public values and corporate priorities. This commentary has argued that bridging the bifurcation of these fields could put social scientists of food and agriculture in a better position to improve discussions about emerging agri-food biotechnology, helping to move from "matters of fact" to "matters of concern" (Latour 2004). It calls for a commitment to both translational scientific communication and a critique of power in understanding the social shaping of science and technology. With attention to the structure, content, and style of engagement, social scientists can play a productive role as conversational conveners and participants across a variety of academic, institutional, community-level, and mediated contexts. Efforts to improve conversation are no guarantee of healthy, equitable, and sustainable food systems, but by complicating the narrative about agri-food biotechnology's promises and limits, a more meaningful dialogue might be on the table.

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Declarations

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