This book was set in Stone Serif and Stone Sans by Toppan Best-set Premedia Limited. Printed and bound in the United States of America.

Library of Congress Cataloging-in-Publication Data

Names: Felt, Ulrike, editor.
Title: The handbook of science and technology studies / edited by Ulrike Felt, Rayvon Fouché, Clark A. Miller, and Laurel Smith-Doerr.
Description: Fourth edition. | Cambridge, MA: The MIT Press, [2017] | Includes bibliographical references and index.
Identifiers: LCCN 2016023009 | ISBN 9780262035682 (hardcover: alk. paper)
Subjects: LCSH: Science. | Technology.
Classification: LCC Q158.5 .H36 2017 | DDC 303.48/3—dc23 LC record available at https://lccn.loc.gov/2016023009

10 9 8 7 6 5 4 3 2 1

30 Reframing Science Communication

Maja Horst, Sarah R. Davies, and Alan Irwin

In current knowledge societies, where technoscience is seen as a key driver for economic growth and national prosperity, science communication represents a crucial activity. Certainly, public communication of science and technology—whether in the form of public engagement or less overtly deliberative formats, such as science media, museums, festivals, and websites—continues to be supported by national and international policies and funding programs. In Europe, for instance, the Horizon 2020 program's emphasis on Responsible Research and Innovation incorporates the aim of building "a more scientifically literate society able to actively participate in and support democratic processes, and science and technology developments" (European Commission 2014). In the United States, the National Science Foundation funds activities that "advance informal learning in science" (National Science Foundation 2015). Furthermore, science communication practice is undergoing a period of experimentation and change, with new formats such as science comedy (Riesch 2015), citizen science (Haklay 2013; Silvertown 2009), and Web 2.0 platforms (Ranger and Bultitude 2014; You 2014) creating a heterogeneous landscape for the public consumption of scientific knowledge (Bucchi and Trench 2014; Holliman et al. 2009a, 2009b; Yeo et al. 2015).

Given this level of interest and activity concerning science communication, but also the theoretical and policy challenges of communicating science, it is hardly surprising that such matters have been central to the development of science and technology studies (STS)—and that STS scholarship has contributed to the development of science communication as a field. Over the last two decades, STS work around what has become known as "public engagement with science" (PES) has been especially prominent, having an impact both upon scholarship in this field but also engagement practice.

However, and as we will discuss, science communication covers a broader area than is implied by PES alone. In that sense, PES is highly significant for science communication but is by no means coterminous with it. Furthermore, science communication brings together a number of classic themes within STS in sometimes novel and provocative ways, including the status of knowledge claims in contemporary society, the relationship between science and democracy, and the role of organizational cultures and institutional arrangements in sociotechnical innovation. Equally, research in science communication has been conducted within STS but also in other fields, for example, in connection with the international Public Communication of Science and Technology (PCST) network. While STS scholarship may have contributed substantially to the field of science communication, not all work within science communication would consider itself to be STS in conceptual and methodological orientation.

This chapter highlights the ways in which the study of science communication can benefit from, and add to, the methods and concerns of STS. Accordingly, it covers both work that has been conducted by STS scholars and research within neighboring fields. It is structured into three sections. First, a scene-setting introduction to science communication and some of the conceptual models that have been developed to describe it; second, a discussion of the key themes that have emerged within recent research and analysis; and third, a presentation of current issues and challenges, including some suggestions for how these might be addressed by future research.

Setting the Scene: Science Communication in Context

Science communication has been a part of science since its earliest days. As Steven Shapin and others have shown, some notion of the public has always been constitutive of the scientific process (Shapin 1990). Overt efforts at improving public awareness and understanding of scientific knowledge similarly have a long history: from Victorian Mechanics' Institutes (Cooter and Pumfrey 1994) and educational pamphlets (Keene 2014) to the activities of "visible scientists" (Goodell 1975) such as Joaquín Gallo, Jane Goodall, Neil deGrasse Tyson, Niels Bohr, and Brian Cox.

There is also a more contemporary history of science communication. As Brian Trench (2008, 119) put it, "Science communication has been telling a story of its own development, repeatedly and almost uniformly, for almost a decade." This dominant story tells of a transition from communication formats marked by "deficit model" approaches to those that emphasize dialogue, debate, and participation (Gregory and Lock 2008). In the United Kingdom, deficit model approaches to communication (understood as assuming a singular, cognitive deficit public whose trust in science will be ensured through the provision of scientific facts; Irwin and Wynne 1996) were often associated with the rise of the "public understanding of science" (or PUS) movement in the 1980s and 1990s (Bodmer 2010; Durant, Evans, and Thomas 1989). In the United States, discussion has rather tended to emphasize "scientific literacy" (Logan

2001; Miller 2004). In both cases, science communication practitioners were expected to respond to the problem of an uninformed—and distrustful—public by efficiently transferring scientific knowledge to them.

The fault line through which contemporary science communication has tended to define itself, then, is a contrast between *deficit* (one-way, elitist, fact-oriented) and *dialogue* (two-way or interactive, participatory, reflective upon technoscience's broader implications). The various conceptual models that have been developed for science communication tend to confirm this. Even where they include three or even four types of communication, the one-way/dialogue contrast is generally pivotal. One such model is provided by Maja Horst (2008), who distinguishes *diffusion* (where the emphasis is on the public listening to science), *deliberation* (with an emphasis on science listening to the public), and *negotiation* (focused on communication as constitutive of social relations) as ways of framing science communication. Other models have been proposed—by Trench (2008) and Palmer and Schibeci (2014), for example—based on a similar diffusion/deliberation (or deficit/dialogue) formulation.

These accounts (and other, similar models of the communication process; see Brossard and Lewenstein 2009; Rowe and Frewer 2005) thus classify science communication according to how knowledge, whether that is scientific or lay, is understood as traveling or being constructed. One noteworthy exception to this is Burns, O'Connor, and Stocklmayer (2003), who focus on the purpose(s) of a science communication activity, and its impacts at the level of individuals, rather than on information flow. Their definition of science communication includes issues of personal awareness with science, enjoyment, interest, and the forming of opinions about science-related matters as well as broader understanding of science's content, processes, and social characteristics.

For the purposes of this chapter, and at least as a starting point for discussion, we define science communication as *organized, explicit, and intended actions that aim to communicate scientific knowledge, methodology, processes, or practices in settings where nonscientists are a recognized part of the audiences*. There are four significant features of this definition.

First, this definition does not specify the sender or producer of the communication—in other words, who is involved aside from "nonscientist audiences." Though much of the academic discussion of, variously, PUS, engagement, and dialogue has tended to focus on those working in science as the key producers of science communication, it is important to note that, today, science communication involves many other kinds of professionals, from university outreach officers to museum "explainers." Science communication is no longer about (only) particular visible scientists but a whole raft of different professionals, organizations, and institutions—including activist groups, campaigners, citizen scientists, and NGOs.

Second, we do not wish to use the directionality or nature of knowledge exchange and production as the key means of defining or classifying science communication. In our view, communication, whether deficit model or dialogic in form, always contains an interactive element. Any kind of science communication, even the most static text or public lecture, will be actively received, reconstructed, and interpreted. In that sense, it is always co-produced. Some communication formats emphasize and make overt this co-production more than others. But the point is that the deficit model of a blank slate public has never held up: publics are never entirely passive, even when communicators assume that they are so.

Third, the definition is deliberately open with regard to the forms and formats it covers. As we will discuss in the next section, all sorts of activities (as defined above) *aim to communicate scientific knowledge, methodology, processes, or practices*: science journalism, blogging, museums, festivals, cafés, and events, certainly, but also deliberative exercises, public consultations, medical appointments, and, perhaps more incidentally, science fiction and advertising.

Fourth, and despite this relative openness, our approach here distinguishes science communication from more general communication. This is an important, but also contestable, point when so much communication in contemporary societies draws upon science-related material (a popular television series such as *Breaking Bad*, advice to households on waste recycling, many pro- or anti-abortion campaigns) but does not fit our definition in terms of the explicit and intended focus on science. One could extend the definition of science communication much more broadly to include all forms of communication which touch (or draw) upon science in some way—or else argue that science communication is simply communication with no special characteristics of its own since science is bound up in so many ways with the practices and experiences of everyday life. Our suggestion is that such moves would miss some important and distinctive features of science communication as an activity (as we will demonstrate in the following sections). However, it is important to stress that in practice the definition of science communication is always open to challenge and reconstruction, and that this definitional issue is an important aspect of the relationship between STS and science communication.

Important Strands of Science Communication

In this section, we introduce three key areas of science communication scholarship, focusing on how STS has contributed to each. We include academic accounts that imply a more or less linear understanding of communication as information transfer, as well as literature which understands communication as a constitutive activity for making sense of the world. For presentational purposes, this section distinguishes between science communication forms and formats (through which scientists and publics come into contact with each other); scientists as communicators; and publics as audiences. Of course, this analytical distinction breaks down as soon as we delve deeper into the research—an issue to which we return in the following section.

Forms and Formats of Science Communication

It has to be acknowledged that academic attention has not been evenly distributed among science communication's different formats. Science PR, for instance, has received rather little attention (but see Bauer and Bucchi 2008). Similarly, science festivals (Bultitude 2014; Jensen and Buckley 2012), science blogging (Riesch and Mendel 2014), and social media and online campaigning (Brossard and Scheufele 2013) are just starting to appear in the literature. However, there have been two particular foci for scholarly attention over the last decade: science in the mass media and activities that fall under the rubric of public engagement.

Some work on science in the mass media pertains to straightforward content analysis: how much, and what kind of, science is presented in science news, TV, or books. For instance, one extensive analysis of the British Broadcasting Corporation's 2009–2010 output found that science was mentioned in half of its TV news programming (Mellor, Webster, and Bell 2011). In another study, Boykoff (2010) reports that the coverage of climate change in fifty leading newspapers around the world increased five times in the period 2004–2009, pointing particularly to the important role of media coverage in the global south. There has been substantial interest in the ways the media frame science stories and particularly how such frames vary among national contexts (Massarani et al. 2013; Priest 2006; Reis 2008). Other analyses have focused specifically on the role of media coverage in public controversies, for instance, describing how such coverage supports the creation of scientific facts (Neresini 2000), influences public trust and risk perception (Durfee 2006; Varughese 2011), and supports certain national narratives (Kruvand and Hwang 2007). Drawing more generally on media studies, there has been an interest in theorizing the likely effects of media coverage of science on the publics who encounter it. Some of this work has focused on agenda setting, framing, priming, and issue arenas (Bauer 2002; Nisbet et al. 2002), while other studies have focused on the notion of medialization to describe the influence of the media logic on the system of science (Rödder, Franzen, and Weingart 2012).

An important and continuing focus within science communication has been public engagement with science, or PES. Developing out of the tradition of researching science-public interactions (for example, Irwin and Wynne 1996) but also from the body of academic work studying the relationship between technical expertise and political decision making (Brown 2015; Nelkin 1975), STS scholars and other social scientists have paid considerable attention to processes of public involvement with (especially) new areas of science and technology (Callon, Lascoumes, and Barthe 2011; Horlick-Jones et al. 2007). This academic field has been stimulated by (and indeed contributed to) a series of policy statements and institutional reports advocating greater societal scrutiny of emerging areas of science and technology (Felt et al. 2013; House of Lords 2000).

While some PES-related activities have been explicitly framed in the context of formal, scientific, decision-making processes (Hagendijk and Irwin 2006; Horlick-Jones et al. 2007), others have developed in connection with science communication institutions such as science museums, universities, and learned societies (Davies et al. 2009; Turney 2006). Again, the range of included activities is large just as there is considerable variation among national and regional contexts: science cafés, public events (such as consensus conferences run by academics), museum events, and university open days have all been discussed under the label of "public engagement" (Bell 2008; Grand 2009; Nishizawa 2005). Typically, such events involve live, face-to-face encounters between scientists and laypeople. Discussion may take place in small groups or in a public lecture or meeting, but the aim is to provide (carefully mediated) opportunities for laypeople to question or interrogate the views and work of scientists (Kerr, Cunningham-Burley, and Tutton 2007). As such, public engagement events often incorporate reflections on the wider implications of contemporary technoscience.

Understanding what happens in, and what results from, public engagement has been a key focus of STS over the last two decades, with research exploring questions of how the public is being defined for these purposes, the frameworks of meaning being imposed (not least in terms of the questions set for discussion; Felt and Fochler 2010), the institutional purposes of engagement (Hagendijk and Irwin 2006), the relationship between specific engagement initiatives, and questions of national identity and political culture (Horst and Irwin 2010; Wu and Qiu 2013; Zhang 2007), the status given to scientific evidence in relation to other forms of knowledge and interpretation (Leach, Scoones, and Wynne 2005; Tironi 2014), and the long-term effects on participants (Davies 2011; Kerr, Cunningham-Burley, and Tutton 2007). In more specific terms, STS treatments of PES have focused on (among other matters) questions of access to information and expertise (Chilvers 2008; Irwin 2006), the handling of doubt, uncertainty, and indeterminacy (Clark 2013; Wynne 1992), the specific form of interactions between scientists and citizens (Irwin 1995; Suryanarayanan and Kleinman 2012), and the design and conduct of deliberative processes (Burgess, Harrison, and Filius 1998; Pellizzoni 2001). Much of this analysis has been critical of institutional activities, presenting specific initiatives as centralized and relatively limited attempts to "capture" public opinions without any underlying commitment to deeper dialogue or principles of democratic governance (Marris 2015; Stilgoe, Lock, and Wilsdon 2014; Welsh and Wynne 2013).

The increasingly important phenomenon of citizen science must also be noted in the context of public engagement with science (Bonney et al. 2016; Ellis and Waterton 2004; Freitag and Pfeffer 2013). As Haklay (2013) has discussed, "citizen science" covers a range of participatory levels from basic crowdsourcing (or the use of citizens as sensors) through forms of "distributed intelligence" to "participatory science" and what he presents as "extreme" citizen science—where there is close collaboration between scientists and nonscientists with regard to such matters as problem definition, data collection, and analysis. As originally developed within STS scholarship, citizen science drew attention both to the manner in which groups of citizens could serve as knowledge generators (and not simply passive recipients of expert knowledge) and to the contextuality of all knowledge claims—whether based on close observation of everyday circumstances or formalized scientific methods (Irwin 1995). Beyond STS, citizen science has become a popular term to describe the engagement of members of the public in scientific projects, for example, surveys of bird populations, astronomical observations, and whale watching (Socientize Project 2014). In terms of our discussion of science communication, citizen science emphasizes both the diversity and distributed expertise of nonscientific audiences and the importance of two-way exchange between citizen and scientific groups. Even in its most "non-extreme" form, citizen science draws attention to the dynamic relationship, and increasingly open borders, between organized science and wider society—with important consequences for the form but also for the content of science communication.

Finally, it will be clear from the work cited above that the *type* of science that is communicated has also been a cross-cutting theme. Media content analysis, for instance, has explored long-term trends in the kinds of science covered in newspapers, finding a growth in medical and health-related news (Bauer et al. 2006). Other work has discussed the role of news values—such as novelty or geographical immediacy—in story selection (Henderson and Kitzinger 2007; Priest 2001). In the context of public engagement, the possibility of allowing public understandings, arguments, and values to shape research priorities has meant that the focus has very often been on new and emerging technologies. Nanotechnology, geoengineering, and synthetic biology have in that way provided important test cases for STS research (see, for example, Bowman and Hodge 2007).

Scientists as Communicators

Traditionally, science communication has been understood as an activity conducted by individual scientists ("visible scientists," in Goodell's terms; 1975). However, the last fifty years have also seen a growing interest in the role of other actors, for example, journalists and the media (Friedman, Dunwoody, and Rogers 1999; Lewenstein 1995), but also professional science communicators employed in consultancies, in research organizations, and working as freelancers (Bennett and Jennings 2011; Neresini and Bucchi 2011). It is nevertheless still the case that scientists are central to science communication and an understanding of their values, attitudes, and motivation structures is crucial (Bauer and Jensen, 2011). Thus, in an early analysis, Hilgartner (1990) pointed to the way in which the particular view of science communication as popularization serves as a political resource for scientists, since it lets them retain authority over what counts as knowledge. Hilgartner's conceptual analysis has been followed by more empirical analyses of how scientists think of their role in science communication (Casini and Neresini 2013; Jia and Liu 2014). These studies generally identify the dominance of a deficit model among scientists.

STS studies have also pinpointed the ways in which scientists employ various "discursive repertoires" (Gilbert and Mulkay 1984) to draw boundaries between science and nonscience (Burchell 2007). In particular, scientists have been described as dissatisfied with media coverage of science, which they tend to find too sensational and dramatic as well as overspeculative and with too much focus on risk (Gunter, Kinderlerer, and Beyleveld 1999). Petersen et al. (2009) point to the fact that this criticism is often coupled with a very poor understanding of the way the media function and scientists' own role in science coverage. However, recent studies have demonstrated that scientists' media contacts are more frequent and generally less problematic than previously thought (Dunwoody, Brossard, and Dudo 2009; Peters et al. 2008).

While the literature described above has focused on scientists' perceptions of the public, the media, and the purpose of science communication, a different set of studies (often drawing upon quantitative communication studies) has focused more directly on scientists' motivations for participating in public communication. In a secondary analysis of two large-scale surveys, Besley, Oh, and Nisbet (2012) found that scientists' attitudes toward public engagement were more significant than demographic factors such as gender and age. Other studies have demonstrated that scientists are motivated by a wish to improve public interest, awareness, understanding, and enthusiasm for science (see, for example, Royal Society 2006). Poliakoff and Webb (2007) found that scientists' previous behavior is the most important predictor for whether they were likely to engage in public communication. However, this study also concluded that scientists' perception of their colleagues' level of engagement influences their own participation in public communication. In a 2014 study, Johnson, Ecklund, and Lincoln investigated disciplinary differences and found that while physicists see public communication as a threat to their scientific reputation and credibility, biologists assign much greater value to a public communication profile.

This overview illustrates that despite various efforts, there is still no coherent understanding of the influence of collective values or disciplinary differences on scientists' decision to engage in science communication. Meanwhile, science communication is primarily presented as an activity carried out by individual scientists. This however might be changing. More recent studies have examined the role of PR departments (Lynch et al. 2014), professional science communicators (Borchelt and Nielsen 2014; Chilvers 2008), and the training of scientists for public communication (Besley, Dudo, and Storksdieck 2015; Miller and Fahy 2009).

Audiences of Science Communication

Research into the audiences of science communication basically falls into two main categories. There is, on the one hand, work exploring how various publics report on their knowledge and attitudes to science. On the other hand, research in STS traditions has investigated how science communication produces its audiences—focusing on the performative character of, for example, engagement processes. The first body of work has relied heavily on surveys of publics, whether general or specific, while the latter has emphasized qualitative analysis of the design and framing of particular engagement formats.

Studies of public understanding of science have a long history (Logan 2001), and general surveys attempting to identify public knowledge of and attitudes toward science remain central (see, for instance, Besley 2013; Castell et al. 2014). Importantly, these studies have demonstrated that there is no simple causal relation between knowing a lot about science and being positive toward it (Allum, Boy, and Bauer 2002; Castelfranchi et al. 2013). General surveys have also sought to uncover what "the public" think of certain technologies, and why (e.g., Pidgeon et al. 2012 for a study of public responses to geoengineering). In a similar vein, just over half of the respondents in a large UK study "think that the benefits of science outweigh any harmful effects"

(Castell et al. 2014, 26). Surveys often report that publics are interested in information about science and technology, and that they choose to consume forms of science communication such as science news, magazines, and museum exhibitions (ibid.; National Science Board 2014). More specifically, evaluative research on specific types of science communication has identified particular audiences for science communication and the different motivations they may express (Jensen and Buckley 2012). Thus, research on public lectures in science centers and museums has identified a number of types of visitor, including students working on the topic under discussion, individuals personally affected by that topic, and friends and family of the lecturer (Rennie and Williams 2006).

In her study of a gallery at the London Science Museum, Sharon Macdonald (1995) found that visitors' reasons for attending were often not much to do with science at all. Rather, they saw their visit as part of a "cultural itinerary" whereby they could, for instance, visit a key attraction in the UK capital or nostalgically re-create childhood visits with their own family. Similarly, she found that visitors' interpretations of the content of the gallery were shaped by their orientations and interests. They were, she writes, "reconfiguring the exhibition, sometimes in ways unanticipated by, or even explicitly contradicting, the makers" (Macdonald 1995, 20). This research suggests that science communication's audiences consume and use it in ways that go beyond simply satisfying an interest in science. Instead, audiences use science communication in the context of, and as part of, their personal, professional, and civic experiences.

The second major theme of research into audiences has emphasized the ways in which they are constituted by the structure of the engagement or communication format. Much of this work has focused on public engagement, exploring the ways in which publics are understood and thereby performed within ostensibly open and accessible formats (Irwin 2001). Braun and Schultz (2010), in reviewing this work, suggest four types of public that are commonly performed. They distinguish the *general* public, the *pure* public, the *affected* public, and the *partisan* public, with the pure and affected publics seen as most valuable within engagement exercises, since they either bring a neutral position or authentic expertise. Similarly, Felt and Fochler (2010) have discussed how the "machinery" of public engagement functions to frame participants, and their role in deliberation, in particular ways. Their discussion also emphasizes that participants do have scope to resist and reimagine those roles and that such imposed versions of the public, whether performed in public engagement or in scientific governance more generally, need not be final.

Current Issues in Science Communication

Taken overall, STS research has, then, served to trouble some of the assumptions which typically frame science communication—for instance, that its formats are innocent (and therefore do not act to constitute or constrain their participants), that it is primarily carried out by scientists, and that its users are motivated by a simple desire to know more science. Analysis of PES and other science communication has also destabilized the idea that science communication is an activity that can be grasped by one or another model of communication. Rather, any kind of science communication is a complex phenomenon and efforts to understand it through one model or analytical lens invariably produce a number of overflows. Even the most dialogically organized public engagement event might disappoint ideals of openness and egalitarianism, just as the most well-planned form of science information can be transformed through irony, appropriated by local social contexts, or simply ignored by audiences (Horst and Michael 2011).

Building on these insights, this section outlines some key issues for current and future research. It is structured around three major ways in which the study of science communication is important for understanding the role of science and technology in society: science communication's significance for the ability to make science, its connection to issues of organizational communication and identity formation, and finally, its importance for issues of democratic governance and citizenship.

Science Communication as Making Science

In Dorothy Nelkin's (1995) classic book about science communication, the fundamental point was that press coverage of science and technology was "selling science" rather than providing critical journalism. In particular, this was the case with new and emerging scientific fields. Building on a long tradition of studying controversies, she pointed to the fact that public communication about science is neither neutral nor objective—rather it is argumentation with the goal of convincing or persuading an audience of a particular state of affairs (Horst 2010).

In a related vein, the theme of futures and future making through communication has been central within STS and the area known as the sociology of expectations (Brown, Rappert, and Webster 2000; van Lente 1993). If actors are to secure a specific kind of future, then they must engage in a range of rhetorical, organizational, and material work in order to bring this future about (Brown, Rappert, and Webster 2000, 3). According to this literature, we should not focus on whether these expectations are justified or hyped in an effort to sell science but rather consider their performativity in the present (Michael 2000). Although visions and expectations are also formed through material and organizational efforts, communication and "storytelling" (Deuten and Rip 2000) represent a key medium through which these expectations are shaped. On this basis, Plesner and Horst (2013) have suggested that we speak of "innovation communication" as an integral part of the innovation process. Such communication aims to generate support for the sociotechnical development in question.

Especially when it comes to the communication of emerging science and technology, it is evident that companies and scientific organizations, as well as involved scientists, are invoking particular futures. For example, Hellsten (2002) demonstrates how life science companies have tried to turn images of fear into those of hope by focusing on health care and suggesting that humankind should take control of nature to make a better future. However, Guice (1999) has pointed to the fact that whereas all new technological trends have to be promoted, promotional work is often most effective when it is invisible. One of the most extreme examples of such unnoticed promotional work is found in the medical publication planning profession, whose job it is to orchestrate publications in order to support marketization of pharmaceutical drugs (Sismondo 2009).

Innovation communication highlights that science communication is not something separate from science but part of the process of generating resources and legitimacy in order to make and maintain it. Inspired by Deuten and Rip (2000), who discuss "product creation processes" as a genre, we suggest that it might be useful to think of innovation communication as something that takes place in many genres. Besides news and media coverage, we might also look at strategic reports (van Lente and Rip 1998), funding applications (Myers 1985), and patents (Packer and Webster 1996). In all these strategic forms of communication, actors aim to influence particular imaginations of technological possibilities and scientific futures in order to mobilize expectations. Pinch (2003) hinted at this when he argued that salespeople are "the missing masses" of technological development and that we should pay more attention to selling as an activity.

Work on the sociology of expectations has also pointed to the fact that expectations—stories about the future—do not just have one author. Rather, scientists and managers of research organizations are always coauthors of stories, which are simultaneously shaped by many other agents: "biotechnology firms (the small as well as the large variety), venture capitalists, retailers, consumer and environmental groups, all collude in creating a multi-actor—and multi-authored—story" (Deuten and Rip 2000, 84). Van Lente and Rip suggest that we think of these authors of visions as "promise champions" and remind us that they "need not be individuals. In fact, in the age of strategic science and technology, a plethora of collective actors has emerged to carry and protect new developments" (1998, 232). Science communication as the selling of science and innovation might therefore not be the result of individuals acting from specific interests but rather of a strategic authorial voice that emerges from an assemblage of relations between individual and collective actors and interests.

Science Communication as Organizational Communication

Simultaneously, organizations are becoming increasingly important to the conduct and understanding of science communication (Casini and Neresini 2013). Certainly, science communication is rapidly being professionalized, in part because (thanks to policy enthusiasm for public engagement) it is now a growth industry and in part because universities and other knowledge-based organizations have become much more focused on their public image and reputation (Bauer and Bucchi 2008). At the same time, science itself is no longer primarily the work of single individuals but a highly organized and collective phenomenon (Shapin 2009). Science communication therefore can no longer be interpreted only as the activity of individual scientists. It is also institutional and professional, and can be understood as a form of organizational communication in universities and other research organizations.

Brass and Rowe (2009) point out that universities' concern with their external reputation is focused around two perceived risks: damage to organizational reputation and damage to the legitimacy of knowledge and expertise. To avoid such damage, universities increasingly enforce prescriptive guidelines for academics' public statements and commentary. While these tendencies suggest that universities are moving toward stricter central control of science communication, it should also be recognized that traditionally there has been a large degree of freedom for individual scientists to speak publicly compared, for example, with employees of most commercial companies (Callagher, Horst, and Husted 2015). It is also important to recognize that scientists often have a dual allegiance (Anderson et al. 1980): to their organization and to their discipline. They might therefore consider disciplinary colleagues in competing research organizations as more a part of their internal organization than professional communication staff in their own organization.

Competition between universities and other research organizations has the potential to drive a celebrity culture (see Fahy 2015), in which high-profile scientists become important parts of the organizational brand. More generally, leading scientists can be seen as foci for the public image of, for instance, a university, acting as internal role models and interpreters of what science is and should be. As an example of the latter, Brosnan and Michael (2014) have shown how, for a research group, the promise of neuroscience being one day translated into clinical practice was embodied and vivified—rendered alive—in the figure of a group leader, whose expertise spanned clinical and basic neurosciences.

Outside of STS, there has been substantial attention to the development of entrepreneurial universities and the motivations for scientists to take up commercial activities. It is a common conclusion that socialization, group norms, and organizational support impact the degree to which individual scientists engage in commercial activities and associated forms of communication (Bercovitz and Feldman 2008; Häussler and Colyvas 2011). STS-inspired analyses have demonstrated that academic and entrepreneurial activities are taking place alongside each other (Lam 2010). This can lead to complicated boundary maintenance arising "from the conflicting procedures and requirements of the two activities as well as from the double roles assumed by the actors involved" (Tuunainen and Knuuttila 2009, 684).

The importance of these perspectives and analyses stems from the fact that they point to the crucial connection between organizational communication and organizational/individual identity formation. Within the symbolic perspective of organizational communication, a crucial point concerns the close links between internal perceptions of identity and external images of the organization (Hatch and Schultz 1997). Thus, the ways in which scientific organizations describe themselves—both externally and internally—are closely related to the ways in which scientists make sense of their own jobs. The branding of the organization, for instance, influences how scientists imagine their own careers (Duberley, Cohen, and Mallon 2006). Felt and Fochler (2012) have pointed to this as an increasingly important issue, since science communication regularly portrays science as a glamorous, business-like and result-focused venture, which junior scientists can struggle to align with their everyday experience of scientific work.

The professionalization of science communication therefore suggests a range of issues connected to changes in the wider academic landscape, the nature of scientific identities, and the way knowledge is branded and represented. Importantly, public communication associated with organizational and sectoral changes toward commercialization and marketization should not just be seen as new ways of packaging knowledge. Rather these organizational changes potentially influence the way in which scientists perceive their own role and that of the organization, thereby also shaping what science is and should be.

Science Communication for Scientific Citizenship

At least two foundational themes have run through STS analyses of public engagement. The first is *power*. STS has been interested in who—and what—is able to speak authoritatively and in which contexts. Research on public engagement activities has often indicated that—regardless of the language of dialogue and participation—such events all too often constrain, rather than enable, lay public involvement in active discussion and questioning of scientific knowledge (Kerr, Cunningham-Burley, and Tutton 2007). The second theme is, relatedly, that of *democracy*. Accounts of public engagement have often, implicitly or explicitly, linked such activities (generally in critical terms) to a larger democratic drive to open up science to public debate and, at least potentially, to empower citizens with regard to scientific decision making (Powell and Colin 2008). That science communication is politically as well as culturally important runs as an undercurrent through almost all discussion of it (Durant, Evans, and Thomas 1989). Yet this raises a series of broader questions. What is the role of science communication in a democratic society? Should it be understood as capacity building and citizen empowerment, or rather as the imposition of reductionist and scientistic forms of understanding (Wynne 2006)?

Stirling (2008) has emphasized the importance of opening up the governance of science and technology to plural and conditional policy advice, revealing alternative courses of action and different framing conditions. In a similar vein, Guston (2014, 234) has presented "anticipatory governance" as a means of "improving the societal capacity to articulate and apply public values in the context of emerging technologies." One key question for science communication then is whether it can adopt this "opening up" role rather than falling back into an older (and deficit-oriented) tradition of seeking to disseminate authoritative knowledge about science and society. In line with Welsh and Wynne (2013), part of this role would be the articulation of different "collective public meanings" and the questioning of normative social commitments to dominant models of science and progress. Seen in this light also, science communication is not simply a matter of dealing with what is conventionally defined as knowledge but is also bound up with questions of governance cultures, institutional learning, and relations of power and ownership—including the manner in which these affect communication structures and processes.

Developing further this citizenship role for science communication, a focus on justice in this context raises questions of democratic rights, of accountability, and of the responsibility to do what is best for the collectivity (including collectivities as yet unborn). Rather than separating questions of power, democracy, and knowledge into separate domains, ideas of cognitive/epistemic (in)justice precisely interconnect and intermingle these two, suggesting also that modes of citizenship and forms of knowledge flow together through many areas of social life (Fricker 2007; Visvanathan 2005). For science communication, this justice dimension suggests many challenging questions of an ethical, political, and sociological kind: What are the societal responsibilities of the science communicator? How does science communication connect with political decision making around science and innovation? How can science communication address vulnerable groups within society?

While questions of citizenship, democracy, and justice might seem to imply a rather traditional model of both scientific governance and science-public relations, STS scholars have also explored alternative ways in which members of society engage with science and society—including the relationship between consumption and citizenship and the manner in which public participation can be “materialized” through objects and devices (Marres 2012; Michael 1998). Taken together with the growing body of scholarship which identifies new governance forms (for example, mixtures of the public and private), fresh perspectives on agency, and the particular challenge of responding to global concerns such as climate change (Sundström, Soneryd, and Furusten 2010), one can identify new questions about the very nature of scientific citizenship but also about the forms of science communication which are required in such settings. Certainly, the theme of “science communication for scientific citizenship” raises profound issues concerning the changing nature of communication in this setting but also its relationship to the problematic character of scientific citizenship.

Conclusion

One immediate lesson from the discussion in this chapter is that science communication can in no way be seen as a narrow topic or a neatly bounded activity. Instead, it sits at a crucial point of intersection and influence between science, technology, and society. As we have suggested, STS is an important part of this broader picture without by any means covering it all. In this concluding section, we first address the implications of STS for science communication before turning the question around in order to consider the linkage between research around science communication and larger themes and issues within STS.

In terms of the contribution of STS to science communication, it seems that STS has been especially valuable in challenging underlying assumptions concerning the nature of science communication, drawing attention to some of the emerging forms and formats of science communication, and developing new themes and concerns (e.g., the linkage between science communication and scientific citizenship). However, we have also noted several areas where a stronger STS contribution could be made to science communication, not least concerning important topics such as the influence of new social media, organizational studies of science communication, and the relationship between science communication activities and the structure of scientific careers.

More generally, there is considerable further scope for STS scholars to bring tools, critical insights, and theoretical perspectives to the study and practice of science communication. Certainly, we are aware that we have only painted with the broadest of brushstrokes in this chapter. In particular, science communication could benefit from a more nuanced understanding of the nature of scientific knowledge and the ways in which it is produced. From our perspective, this might develop a more sophisticated treatment of what is being communicated (i.e., of the science itself) but also encourage greater reflection on the very idea of science communication and how it is to be defined, bounded, and enacted. Crucially, this should include the question of how and when institutions employ the language of science to deal with what might otherwise be presented as political, ethical, and cultural views and arguments concerning the direction of innovation or the desirability of new goods and processes.

Turning to the linkage between research in this particular field and larger themes within STS as a whole (i.e., of what science communication can do for STS), there are many possibilities. Certainly, the notions that science communication should be seen not as a side activity but as a crucial form of co-production, that the presentation of science can also be a matter of organizational identity building, and that questions of epistemic justice deserve larger scholarly and political attention have significant implications for STS as a whole.

Going further, research in science communication draws attention to the role that informal engagement with science can play in scientific citizenship. In that way it enables STS scholars to observe how lay citizens use museums, popular science, or the Internet as parts of their civic lives. Equally, the foregrounding by science communication research of emotional and aesthetic responses to science—such as pleasure, excitement, entertainment, wonder, and fear—brings a new dimension to the still largely epistemic orientation of STS. More broadly, science communication encourages STS to look beyond scientific organizations, industry, and the state as sites in which science is created and negotiated, and calls attention to science-related activism, citizen science, and "garage science" as general phenomena which may disturb conventional ideas of scientific institutions and scientific practice. As we have suggested above, science communication research regularly demonstrates not simply the public absorption of scientific messages but also the co-construction of new forms of knowledge, often in unconventional locations.

Science communication is both an important topic and also a complex, crosscutting, and problematic activity. As we hope to have suggested in this chapter, science communication in many ways takes us to the heart of STS as a body of research and practice. As this chapter closes, we are very sure that the potential for further scholarship and reflective practice extends considerably beyond the crowded overview presented here. Already, we look forward to the treatment of science communication in the next edition of the STS handbook.

References

Allum, Nick, Daniel Boy, and Martin Bauer. 2002. "European Regions and the Knowledge Deficit Model." In *Biotechnology: The Making of a Global Controversy*, edited by Martin Bauer and George Gaskell, 224–43. Cambridge: Cambridge University Press.

Anderson, Robert Morris, Robert Perucci, Dan E. Schendel, and Leon E. Trachtman. 1980. *Divided Loyalties: Whistle-Blowing at BART*. West Lafayette, IN: Purdue University Press.

Bauer, Martin W. 2002. "Arenas, Platforms, and the Biotechnology Movement." *Science Communication* 24 (2): 144–61.

Bauer, Martin W., and Massimiano Bucchi 2008. *Journalism, Science and Society: Science Communication between News and Public Relations*. London: Routledge.

Bauer, Martin W., and Pablo Jensen. 2011. "The Mobilization of Scientists for Public Engagement." *Public Understanding of Science* 20 (1): 3–11.

Bauer, Martin W., Kristina Petkova, Pepka Boyadjieva, and Galin Gornev. 2006. "Long-Term Trends in the Public Representation of Science across the 'Iron Curtain': 1946–1995." *Social Studies of Science* 36 (1): 99–131.

Bell, Larry. 2008. "Engaging the Public in Technology Policy: A New Role for Science Museums." *Science Communication* 29 (3): 386–98.

Bennett, David J., and Richard C. Jennings, eds. 2011. *Successful Science Communication: Telling It Like It Is*. Cambridge: Cambridge University Press.

Bercovitz, Janet, and Maryann Feldman. 2008. "Academic Entrepreneurs: Organizational Change at the Individual Level." *Organization Science* 19 (1): 69–89.

Besley, John C. 2013. "The State of Public Opinion Research on Attitudes and Understanding of Science and Technology." *Bulletin of Science, Technology & Society* 33 (1–2): 12–20.

Besley, John C., Anthony Dudo, and Martin Storksdieck. 2015. "Scientists' Views about Communication Training." *Journal of Research in Science Teaching* 52 (2): 199–220.

Besley, John C., Sang Hwa Oh, and Matthew Nisbet. 2012. "Predicting Scientists' Participation in Public Life." *Public Understanding of Science* 22 (8): 971–87.

Bodmer, Walter. 2010. *Public Understanding of Science: The BA, the Royal Society and COPUS*. Notes and Records of the Royal Society. Accessed at http://rsnr.royalsocietypublishing.org/content/early/2010/06/16/rsnr.2010.0035.

Bonney, Rick, Tina B. Phillips, Heidi L. Ballard, and Jody W. Enck. 2016. "Can Citizen Science Enhance Public Understanding of Science?" *Public Understanding of Science* 25 (1): 2–16.

Borchelt, Rick, and Kristian Hvidtfelt Nielsen. 2014. "Public Relations in Science." In *Handbook of Public Communication of Science and Technology*. 2nd ed., edited by Massimiano Bucchi and Brian Trench, 58–69. London: Routledge.

Bowman, Diana M., and Graeme A. Hodge. 2007. "Nanotechnology and Public Interest Dialogue: Some International Observations." *Bulletin of Science, Technology and Society* 27 (2): 118–32.

Boykoff, Max. 2010. "Indian Media Representations of Climate Change in a Threatened Journalistic Ecosystem." *Climatic Change* (99): 17–25.

Brass, Kylie, and David Rowe. 2009. "Knowledge Limited: Public Communication, Risk and University Media Policy." *Continuum: Journal of Media & Cultural Studies* 23 (1): 53–76.

Braun, Kathrin, and Susanne Schultz. 2010. "'… A Certain Amount of Engineering Involved': Constructing the Public in Participatory Governance Arrangements." *Public Understanding of Science* 19 (4): 403–19.

Brosnan, Caragh, and Mike Michael. 2014. "Enacting the 'Neuro' in Practice: Translational Research, Adhesion and the Promise of Porosity." *Social Studies of Science* 44 (5): 680–700.

Brossard, Dominique, and Bruce V. Lewenstein. 2009. "A Critical Appraisal of Models of Public Understanding of Science." In *Understanding and Communicating Science: New Agendas in Communication*, edited by LeeAnn Kahlor and Patricia Stout, 11–39. New York: Taylor and Francis.

Brossard, Dominique, and Dietram A. Scheufele. 2013. "Science, New Media, and the Public." *Science* 339 (6115): 40–41.

Brown, Mark B. 2015. "Politicizing Science: Conceptions of Politics in Science and Technology Studies." *Social Studies of Science* 45: 3–30.

Brown, Nik, Brian Rappert, and Andrew Webster, eds. 2000. *Contested Futures: A Sociology of Prospective Techno-Science*. Aldershot: Ashgate.

Bucchi, Massimiano, and Brian Trench. 2014. *Handbook of Public Communication of Science and Technology*. 2nd ed. New York: Routledge.

Bultitude, Karen. 2014. "Science Festivals: Do They Succeed in Reaching beyond the 'Already Engaged'?" *JCOM: Journal of Science Communication* 13 (4): C01.

Burchell, Kevin. 2007. "Empiricist Selves and Contingent 'Others': The Performative Function of the Discourse of Scientists Working in Conditions of Controversy." *Public Understanding of Science* 16 (2): 145–62.

Burgess, Jacquie, Carolyn M. Harrison, and Petra Filius. 1998. "Environmental Communication and the Cultural Politics of Environmental Citizenship." *Environment and Planning A* 30 (8): 1445–60.

Burns, Timothy W., David J. O'Connor, and Susan M. Stocklmayer. 2003. "Science Communication: A Contemporary Definition." *Public Understanding of Science* 12 (2): 183–202.

Callagher, Lisa, Maja Horst, and Kenneth Husted. 2015. "Exploring Societal Responses towards Managerial Prerogative in Entrepreneurial Universities." *International Journal of Learning and Change* 8 (1): 64–82.

Callon, Michel, Pierre Lascoumes, and Yannick Barthe. 2011. *Acting in an Uncertain World: An Essay on Technical Democracy*. Cambridge, MA: MIT Press.

Casini, Silvia, and Federico Neresini. 2013. "Behind Closed Doors: Scientists' and Science Communicators' Discourses on Science in Society." *TECNOSCIENZA: Italian Journal of Science and Technology Studies* 3 (2): 37–62.

Castelfranchi, Yurij, Elaine Meire Vilela, Luciana Barreto de Lima, Ildeu de Castro Moreira, and Luisa Massarani. 2013. "Brazilian Opinions about Science and Technology: The Paradox of the Relation between Information and Attitudes." *História, Ciências, Saúde-Manguinhos* 20: 1163–83.

Castell, Sarah, Anne Charlton, Michael Clemence, Nick Pettigrew, Sarah Pope, Anna Quigley, Jayesh Navin Shah, and Tim Silman. 2014. *Public Attitudes to Science 2014*. London: Department for Business, Innovation and Skills. Accessed at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/348830/bis-14-p111-public-attitudes-to-science-2014-main.pdf.

Chilvers, Jason. 2008. "Deliberating Competence: Theoretical and Practitioner Perspectives on Effective Participatory Appraisal Practice." *Science, Technology, & Human Values* 33 (2): 155–85.

Clark, Lisa. 2013. "Framing the Uncertainty of Risk: Models of Governance for Genetically Modified Foods." *Science and Public Policy* 40: 479–91.

Cooter, Roger, and Stephen Pumfrey. 1994. "Separate Spheres and Public Places: Reflections on the History of Science Popularization and Science in Popular Culture." *History of Science* 32 (3): 237–67.

Davies, Sarah R. 2011. "How We Talk When We Talk about Nano: The Future in Laypeople's Talk." *Futures* 43 (3): 317–26.

Davies, Sarah, Ellen McCallie, Elin Simonsson, Jane L. Lehr, and Sally Duensing. 2009. "Discussing Dialogue: Perspectives on the Value of Science Dialogue Events That Do Not Inform Policy." *Public Understanding of Science* 18 (3): 338–53.

Deuten, J. Jasper, and Arie Rip. 2000. "Narrative Infrastructure in Product Creation Processes." *Organization* 7 (1): 69–93.

Duberley, Joanne, Laurie Cohen, and Mary Mallon. 2006. "Constructing Scientific Careers: Change, Continuity and Context." *Organization Studies* 27 (8): 1131–51.

Dunwoody, Sharon, Dominique Brossard, and Anthony Dudo. 2009. "Socialization or Rewards? Predicting US Scientist–Media Interactions." *Journalism & Mass Communication Quarterly* 86 (2): 299–314.

Durant, John, Geoffrey Evans, and Geoffrey P. Thomas. 1989. "The Public Understanding of Science." *Nature* 340: 11–14.

Durfee, Jessica L. 2006. "'Social Change' and 'Status Quo' Framing Effects on Risk Perception: An Exploratory Experiment." *Science Communication* 27 (4): 459–95.

Ellis, Rebecca, and Claire Waterton. 2004. "Environmental Citizenship in the Making: The Participation of Volunteer Naturalists in UK Biological Recording and Biodiversity Policy." *Science and Public Policy* 31 (2): 95–105.

European Commission, 2014. *Public Engagement in Responsible Research and Innovation*. Accessed at http://ec.europa.eu/programmes/horizon2020/en/h2020-section/public-engagement-responsible-research-and-innovation.

Fahy, Declan. 2015. *The New Celebrity Scientists*. London: Rowman & Littlefield.

Felt, Ulrike, Daniel Barben, Alan Irwin, Pierre-Benoît Joly, Arie Rip, Andy Stirling, and Tereza Stöckelová. 2013. *Science in Society: Caring for Our Futures in Turbulent Times*. Strasbourg: European Science Foundation.

Felt, Ulrike, and Maximilian Fochler. 2010. "Machineries for Making Publics: Inscribing and Describing Publics in Public Engagement." *Minerva* 48 (3): 219–38.

___. 2012. "Re-ordering Epistemic Living Spaces: On the Tacit Governance Effects of the Public Communication of Science." In *The Sciences' Media Connection: Public Communication and Its Repercussions*, edited by Simone Roedder, Martina Franzen, and Peter Weingart, vol. 28, 133–54. Sociology of the Sciences Yearbook. Dordrecht: Springer.

Freitag, Amy, and Max J. Pfeffer. 2013. "Process, Not Product: Investigating Recommendations for Improving Citizen Science 'Success.'" *PLoS ONE* 8 (5): e64079.

Fricker, Miranda. 2007. *Epistemic Injustice: Power and the Ethics of Knowing*. Oxford: Oxford University Press.

Friedman, Sharon M., Sharon Dunwoody, and Carol S. Rogers. 1999. *Communicating Uncertainty: Media Coverage of New and Controversial Science*. Mahwah, NJ: Lawrence Erlbaum.

Gilbert, Nigel, and Michael Mulkay. 1984. *Opening Pandora's Box: A Sociological Analysis of Scientists' Discourse*. Cambridge: Cambridge University Press.

Goodell, Rae. 1975. *The Visible Scientists*. Boston: Little, Brown.

Grand, Ann. 2009. "Cafe Scientifique." In *Practising Science Communication in the Information Age: Theorising Professional Practices*, edited by Richard Holliman, Jeff Thomas, Sam Smidt, Eileen Scanlon, and Elizabeth Whitelegg. Oxford: Oxford University Press.

Gregory, Jane, and Simon J. Lock. 2008. "The Evolution of 'Public Understanding of Science': Public Engagement as a Tool of Science Policy in the UK." *Sociology Compass* 2 (4): 1252–65.

Guice, Jon. 1999. "Designing the Future: The Culture of New Trends in Science and Technology." *Research Policy* 28: 81–98.

Gunter, Barrie, Julian Kinderlerer, and Deryck Beyleveld. 1999. “The Media and Public Understanding of Biotechnology: A Survey of Scientists and Journalists.” *Science Communication* 20 (4): 373–94.

Guston, David H. 2014. ”Understanding ‘Anticipatory Governance.’” *Social Studies of Science* 44 (2): 218–42.

Hagendijk, Rob, and Alan Irwin. 2006. “Public Deliberation and Governance: Engaging with Science and Technology in Contemporary Europe.” *Minerva* 44 (2): 167–84.

Haklay, Muki. 2013. “Citizen Science and Volunteered Geographic Information: Overview and Typology of Participation.” In *Crowdsourcing Geographic Knowledge*, edited by Daniel Sui, Sarah Elwood, and Michael Goodchild, 105–22. Berlin: Springer Verlag.

Hatch, Mary Jo, and Majken Schultz. 1997. “Relations between Organizational Culture, Identity and Image.” *European Journal of Marketing* 31 (5/6): 356–66.

Häussler, Carolin, and Jeannette A. Colyvas. 2011. “Breaking the Ivory Tower: Academic Entrepreneurship in the Life Sciences in UK and Germany.” *Research Policy* 40 (1): 41–54.

Hellsten, Iina. 2002. “Selling the Life Sciences: Promises of a Better Future in Biotechnology Advertisements.” *Science as Culture* 11 (4): 459–79.

Henderson, Lesley, and Jenny Kitzinger. 2007. “Orchestrating a Science ‘Event’: The Case of the Human Genome Project.” *New Genetics and Society* 26 (1): 65–83.

Hilgartner, Stephen. 1990. “The Dominant View of Popularization: Conceptual Problems, Political Uses.” *Social Studies of Science* 20 (3): 519–39.

Holliman, Richard, Jeff Thomas, Sam Smidt, Eileen Scanlon, and Elizabeth Whitelegg. 2009a. *Practising Science Communication in the Information Age: Theorising Professional Practices*. Oxford: Oxford University Press.

Holliman, Richard, Elizabeth Whitelegg, Eileen Scanlon, Sam Smidt, and Jeff Thomas. 2009b. *Investigating Science Communication in the Information Age: Implications for Public Engagement and Popular Media*. Oxford: Oxford University Press.

Horlick-Jones, Tom, John Walls, Gene Rowe, Nick Pidgeon, Wouter Poortinga, Graham Murdock, and Tim O’Riordian. 2007. *The GM Debate: Risk, Politics and Public Engagement*. New York: Routledge.

Horst, Maja. 2008. “In Search of Dialogue: Staging Science Communication in Consensus Conferences.” In *Communicating Science in Social Contexts*, edited by Donghong Cheng, Michel Claessens, Toss Gascoigne, Jenni Metcalfe, Bernard Schiele, and Shunke Shi, 259–74. Dordrecht: Springer.

___. 2010. “Collective Closure? Public Debate as the Solution to Controversies about Science and Technology.” *Acta Sociologica* 53 (3): 195–211.

Horst, Maja, and Alan Irwin. 2010. “Nations at Ease with Radical Knowledge: On Consensus, Consensusing and False Consensusness.” *Social Studies of Science* 40 (1): 105–26.

Horst, Maja, and Mike Michael. 2011. "On the Shoulders of Idiots: Re-thinking Science Communication as 'Event.'" *Science as Culture* 20 (3): 283–306.

House of Lords. 2000. *Third Report: Science and Society*. London: The Stationery Office, Parliament. Accessed at http://www.publications.parliament.uk/pa/ld199900/ldselect/ldsctech/38/3801.htm.

Irwin, Alan. 1995. *Citizen Science: A Study of People, Expertise and Sustainable Development*. London: Routledge.

___. 2001. "Constructing the Scientific Citizen: Science and Democracy in the Biosciences." *Public Understanding of Science* 10 (1): 1–18.

___. 2006. "The Politics of Talk: Coming to Terms with the 'New' Scientific Governance." *Social Studies of Science* 36 (2): 299–320.

Irwin, Alan, and Brian Wynne. 1996. *Misunderstanding Science? The Public Reconstruction of Science and Technology*. Cambridge: Cambridge University Press.

Jensen, Eric, and Nicola Buckley. 2012. "Why People Attend Science Festivals: Interests, Motivations and Self-Reported Benefits of Public Engagement with Research." *Public Understanding of Science* 23 (5): 557–73.

Jia, Hepeng, and Li Liu. 2014. "Unbalanced Progress: The Hard Road from Science Popularisation to Public Engagement with Science in China." *Public Understanding of Science* 23 (1): 32–37.

Johnson, David R., Elaine Howard Ecklund, and Anne E. Lincoln. 2014. "Narratives of Science Outreach in Elite Contexts of Academic Science." *Science Communication* 36 (1): 81–105.

Keene, Melanie. 2014. "Familiar Science in Nineteenth-Century Britain." *History of Science* 52 (1): 53–71.

Kerr, Anne, Sarah Cunningham-Burley, and Richard Tutton. 2007. "Shifting Subject Positions: Experts and Lay People in Public Dialogue." *Social Studies of Science* 37: 385–411.

Kruvand, Marjorie, and Sungwook Hwang. 2007. "From Revered to Reviled: A Cross-Cultural Narrative Analysis of the South Korean Cloning Scandal." *Science Communication* 29 (2): 177–97.

Lam, Alice. 2010. "From 'Ivory Tower Traditionalists' to 'Entrepreneurial Scientists'? Academic Scientists in Fuzzy University–Industry Boundaries." *Social Studies of Science* 40 (2): 307–40.

Leach, Melissa, Ian Scoones, and Brian Wynne, eds. 2005. *Science and Citizens: Globalization and the Challenge of Engagement*. London: Zed Press.

Lewenstein, Bruce V. 1995. "From Fax to Facts: Communication in the Cold Fusion Saga." *Social Studies of Science* 25 (3): 403–36.

Logan, Robert A. 2001. "Science Mass Communication: Its Conceptual History." *Science Communication* 23 (2): 135–63.

Lynch, John, Desire Bennett, Alison Luntz, Court Toy, and Eva VanBenschoten. 2014. "Bridging Science and Journalism: Identifying the Role of Public Relations in the Construction and Circulation of Stem Cell Research among Laypeople." *Science Communication* 36 (4): 479–501.

Macdonald, Sharon. 1995. "Consuming Science: Public Knowledge and the Dispersed Politics of Reception among Museum Visitors." *Media, Culture and Society* 17 (1): 13–29.

Marres, Noortje. 2012. *Material Participation: Technology, the Environment and Everyday Publics*. Basingstoke: Palgrave Macmillan.

Marris, Claire. 2015. "The Construction of Imaginaries of the Public as a Threat to Synthetic Biology." *Science as Culture* 24 (1): 83–98.

Massarani, Luisa, Dominique Brossard, Carla Almeida, Bruno Buys, and Emily Acosta Lewis. 2013. "Media Frame Building and Culture: Transgenic Crops in Two Brazilian Newspapers during the 'Year of Controversy.'" *E-Compós* 16 (1).

Mellor, Felicity, Stephen Webster, and Alice Bell. 2011. *Content Analysis of the BBC's Science Coverage: Review of the Impartiality and Accuracy of the BBC's Coverage of Science*. London: BBC.

Michael, Mike. 1998. "Between Citizen and Consumer: Multiplying the Meanings of 'Public Understanding of Science.'" *Public Understanding of Science* 7: 313–27.

___. 2000. "Futures of the Present: From Performativity to Prehension." In *Contested Futures: A Sociology of Prospective Techno-Science*, edited by Nik Brown, Brian Rappert, and Andrew Webster, 21–39. Aldershot: Ashgate.

Miller, Jon D. 2004. "Public Understanding of, and Attitudes toward, Scientific Research: What We Know and What We Need to Know." *Public Understanding of Science* 13 (3): 273–94.

Miller, Steve, and Declan Fahy. 2009. "Can Science Communication Workshops Train Scientists for Reflexive Public Engagement? The ESConet Experience." *Science Communication* 31 (1): 116–26.

Myers, Greg. 1985. "The Social Construction of Two Biologists' Proposals." *Written Communication* 2 (3): 219–45.

National Science Board. 2014. *Science and Engineering Indicators 2014*. Arlington, VA: National Science Foundation.

National Science Foundation. 2015. *Advancing Informal STEM Learning Program*. Accessed at http://informalscience.org/nsf-aisl.

Nelkin, Dorothy. 1975. "The Political Impact of Technical Expertise." *Social Studies of Science* 5 (1): 35–54.

___. 1995. *Selling Science: How the Press Covers Science and Technology*. New York: W. H. Freeman.

Neresini, Federico. 2000. "And Man Descended from the Sheep: The Public Debate on Cloning in the Italian Press." *Public Understanding of Science* 9: 359–82.

Neresini, Federico, and Massimiano Bucchi. 2011. "Which Indicators for the New Public Engagement Activities? An Exploratory Study of European Research Institutions." *Public Understanding of Science* 20 (1): 64–79.

Nisbet, Matthew C., Dietram A. Scheufele, James Shanahan, Patricia Moy, Dominique Brossard, and Bruce V. Lewenstein. 2002. "Knowledge, Reservations, or Promise? A Media Effects Model for Public Perceptions of Science and Technology." *Communication Research* 29 (5): 584–608.

Nishizawa, Mariko. 2005. "Citizen Deliberations on Science and Technology and Their Social Environments: Case Study on the Japanese Consensus Conference on GM Crops." *Science and Public Policy* 32 (6): 479–89.

Packer, Kathryn, and Andrew Webster. 1996. "Patenting Culture in Science: Reinventing the Scientific Wheel of Credibility." *Science, Technology, & Human Values* 21 (4): 427–53.

Palmer, Sarah E., and Renato A. Schibeci. 2014. "What Conceptions of Science Communication Are Espoused by Science Research Funding Bodies?" *Public Understanding of Science* 23 (5): 511–27.

Pellizzoni, Luigi. 2001. "The Myth of the Best Argument: Power, Deliberation and Reason." *British Journal of Sociology* 52: 59–86.

Peters, Hans Peter, Dominique Brossard, Suzanne de Cheveigne, Sharon Dunwoody, Monika Kallfass, Steve Miller, and Shoji Tsuchida. 2008. "Interactions with the Mass Media." *Science* 321 (5886): 204.

Petersen, Alan, Alison Anderson, Stuart Allan, and Clare Wilkinson. 2009. "Opening the Black Box: Scientists' Views on the Role of the News Media in the Nanotechnology Debate." *Public Understanding of Science* 18 (5): 512–30.

Pidgeon, Nick, Adam Corner, Karen Parkhill, Alexa Spence, Catherine Butler, and Wouter Poortinga. 2012. "Exploring Early Public Responses to Geoengineering." *Philosophical Transactions of the Royal Society A: Mathematical Physical and Engineering Sciences* 370 (1974): 4176–96.

Pinch, Trevor. 2003. "Giving Birth to New Users: How the Minimoog Was Sold to Rock and Roll." In *How Users Matter: The Co-construction of Users and Technology*, edited by Nelly Oudshoorn and Trevor Pinch, 247–70. Cambridge, MA: MIT Press.

Plesner, Ursula, and Maja Horst. 2013. "Before Stabilization." *Information, Communication & Society* 16 (7): 1115–38.

Poliakoff, Ellen, and Thomas L. Webb. 2007. "What Factors Predict Scientists' Intentions to Participate in Public Engagement of Science Activities?" *Science Communication* 29 (2): 242–63.

Powell, Maria C., and Mathilde Colin. 2008. "Meaningful Citizen Engagement in Science and Technology: What Would It Really Take?" *Science Communication* 30 (1): 126–36.

Priest, Susanna Hornig. 2001. "Cloning: A Study in News Production." *Public Understanding of Science* 10: 59–69.

___. 2006. "The Public Opinion Climate for Gene Technologies in Canada and the United States: Competing Voices, Contrasting Frames." *Public Understanding of Science* 15 (1): 55–71.

Ranger, Mathieu, and Karen Bultitude. 2016. "'The Kind of Mildly Curious Sort of Science Interested Person Like Me': Science Bloggers' Practices Relating to Audience Recruitment." *Public Understanding of Science* 25 (3): 361–78.

Rennie, Léonie J., and Gina F. Williams. 2006. "Adults' Learning about Science in Free-Choice Settings." *International Journal of Science Education* 28 (8): 871–93.

Reis, Raul. 2008. "How Brazilian and North American Newspapers Frame the Stem Cell Research Debate." *Science Communication* 29 (3): 316–34.

Riesch, Hauke. 2015. "Why Did the Proton Cross the Road? Humour and Science Communication." *Public Understanding of Science* 24 (7): 768–75.

Riesch, Hauke, and Jonathan Mendel. 2014. "Science Blogging: Networks, Boundaries and Limitations." *Science as Culture* 23 (1): 51–72.

Rödder, Simone, Martina Franzen, and Peter Weingart, eds. 2012. *The Sciences' Media Connection: Public Communication and Its Repercussions*, vol. 28. Sociology of the Sciences Yearbook. Dordrecht: Springer.

Rowe, Gene, and Lynn J. Frewer. 2005. "A Typology of Public Engagement Mechanisms." *Science, Technology, & Human Values* 30 (2): 251–90.

Royal Society. 2006. *Science and the Public Interest: Communicating the Results of New Scientific Research to the Public*. London: The Royal Society.

Shapin, Steven. 1990. "Science and the Public." In *Companion to the History of Modern Science*, edited by R. C. Olby, Geoffrey N. Cantor, John R. R Christie, and M. J. S. Hodge, 990–1007. London: Routledge.

___. 2009. *The Scientific Life: A Moral History of a Late Modern Vocation.* Chicago: University of Chicago Press.

Silvertown, Jonathan. 2009. "A New Dawn for Citizen Science." *Trends in Ecology & Evolution* 24 (9): 467–71.

Sismondo, Sergio. 2009. "Ghosts in the Machine: Publication Planning in the Medical Sciences." *Social Studies of Science* 39 (2): 171–98.

Socientize Project. 2014. *Green Paper on Citizen Science for Europe: Towards a Society of Empowered Citizens and Enhanced Research*. Socientize/European Commission.

Stilgoe, Jack, Simon J. Lock, and James Wilsdon. 2014. "Why Should We Promote Public Engagement with Science?" *Public Understanding of Science* 23 (1): 4–15.

Stirling, Andrew. 2008. "'Opening Up' and 'Closing Down': Power, Participation, and Pluralism in the Social Appraisal of Technology." *Science, Technology, & Human Values* 33 (2): 262–94.

Sundström, Göran, Linda Soneryd, and Staffan Furusten. 2010. *Organizing Democracy: The Construction of Agency in Practice*. Northampton, MA: Edward Elgar.

Suryanarayanan, Sainath, and Daniel L. Kleinman. 2012. "Be(e)coming Experts: The Controversy over Insecticides in the Honey Bee Colony Collapse Disorder." *Social Studies of Science* 43 (2): 215–40.

Tironi, Manuel. 2014. "Disastrous Publics: Counter-enactments in Participatory Experiments." *Science, Technology, & Human Values* 40 (4): 564–87.

Trench, Brian. 2008. "Towards an Analytical Framework of Science Communication Models." In *Communicating Science in Social Contexts*, edited by Donghong Cheng, Michel Claessens, Toss Gascoigne, Jenni Metcalfe, Bernard Schiele, and Shunke Shi, 119–35. Springer.

Turney, Jon. 2006. *Engaging Science: Thoughts, Deeds, Analysis and Action*. London: Wellcome Trust.

Tuunainen, Juha Kalevi, and Tarja Tellervo Knuuttila. 2009. "Intermingling Academic and Business Activities: A New Direction for Science and Universities?" *Science, Technology, & Human Values* 34 (6): 684–704.

van Lente, Harro. 1993. *Promising Technology: The Dynamics of Expectations in Technological Developments*. Ph.D. thesis. University of Twente, Enschede, Netherlands.

van Lente, Harro, and Arie Rip. 1998. "The Rise of Membrane Technology: From Rhetorics to Social Reality." *Social Studies of Science* 28 (2): 221–54.

Varughese, Shiju Sam. 2011. "Media and Science in Disaster Contexts: Deliberations on Earthquakes in the Regional Press in Kerala, India." *Spontaneous Generations: A Journal for the History and Philosophy of Science* 5 (1): 36–43.

Visvanathan, Shiv. 2005. "Knowledge, Justice and Democracy." In *Science and Citizens: Globalization and the Challenge of Engagement*, edited by Melissa Leach, Ian Scoones, and Brian Wynne, 83–100. London: Zed Books.

Welsh, Ian, and Brian Wynne. 2013. "Science, Scientism and Imaginaries of Publics in the UK: Passive Objects, Incipient Threats." *Science as Culture* 22 (4): 540–66.

Wu, Guosheng, and Hui Qiu. 2013. "Popular Science Publishing in Contemporary China." *Public Understanding of Science* 22 (5): 521–29.

Wynne, Brian. 1992. "Uncertainty and Environmental Learning: Reconceiving Science and Policy in the Preventive Paradigm." *Global Environmental Change* 2 (2): 111–27.

___. 2006. "Public Engagement as a Means of Restoring Trust: Hitting the Notes but Missing the Music?" *Community Genetics* 9: 211–20.

Yeo, Sara K., Michael A. Xenos, Dominique Brossard, and Dietram A. Scheufele. 2015. "Selecting Our Own Science How Communication Contexts and Individual Traits Shape Information Seeking." *The Annals of the American Academy of Political and Social Science* 658 (1): 172–91.

You, Jia. 2014. "Who Are the Science Stars of Twitter?" *Science* 345 (6203): 1440–41.

Zhang, Xiaoling. 2007. "Breaking News, Media Coverage and 'Citizen's Right to Know' in China." *Journal of Contemporary China* 16 (53): 535–45.