View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by DCU Online Research Access Service

Introduction to Public Communication of Science – Critical Concepts in Sociology

Massimiano Bucchi and Brian Trench

There were Roman aqueducts before there was 'engineering', and science was being communicated in public before there was 'science communication'. For centuries, professional societies and academies have organised public lectures and demonstrations. There were times when science talks and public experiments were the hottest tickets in town. Popularisation, as it was called, was an integral part of the lives of leading scientists and scientific institutions. But specialisation and professionalization in science in the late 19th century progressively distanced scientists from public spaces.

Popular science had to be reinvented in the inter-war years of the 20th century when progressive scientists dedicated their efforts to explaining science "for everyone". In the years after World War II – and notably in a Cold War context – public communication and literacy in science became government policy issues. More recently, and increasingly rapidly, this explicit concern with public communication of science in policy, educational and scientific circles has spread through other social sectors and around the world. Public communication of science is a recognised policy issue and an object of study and analysis across the globe.

Scientific discoveries and research findings are constituted in the act of communication, that is, in publication for the attention and critical scrutiny of peers. Professional communication takes place by long-established means through academic journals, the best-known of which have continuous histories of over 150 years. The sociological and institutional characteristics of communication of science within and between scientific communities are distinct from those of public communication of science. This professional communication is sometimes referred to as 'scientific communication' to distinguish it from 'science communication', in which attention is given to the challenges of communicating often highly specialised and complex information with non-specialist members of the public.

Based on this distinction there have grown sets of professional practices, of cultural institutions, of educational programmes and of research activity labelled as science communication, or some near-equivalent. Public communication of science has often been conceptualised in terms of gaps and bridges between scientists and their institutions, on the one hand, and the rest of society, on the other. Scientists' alleged failure or inability to communicate with the public has been set alongside the public's supposed failure to grasp essential scientific facts and concepts. Science communication came to be marked out as a field of problems and misunderstandings, where natural sciences, social sciences, humanities, the policy sector, media and lay publics all occupied their respective plots in unfriendly neighbourliness.

That, at least, is how it might have appeared to the casual observer and that, to some extent, is how the issues in science communication have been played out – as a game of naming and blaming. But these

issues have always deserved more comprehensive consideration and over the last fifty years, and at greater intensity in the last twenty years, they have received analytical attention from scholars and reflective practitioners. Through the perspectives of various disciplines and the endeavours of various professions science communication has come to accommodate professional development courses, postgraduate education programmes, local, national and international networks of practitioners in museums, public information and media, specialist academic journals, doctoral research programmes, international surveys and inquiries, and much more.

Accompanying and influencing this dramatic expansion has been a body of commentary, critique, reflection and empirical studies. We have aimed to collect some of the best examples of this literature, some academic, some advisory, some anecdotal, to represent science communication as a fertile field of intellectual exploration and even an emerging discipline.

As our definition of science communication and the title of this collection both rely on the previously mentioned distinction between professional and public spheres, it is worth noting that this distinction is becoming increasingly difficult to sustain. Recent work has explored how the logics of public media are applied in the conduct of professional science and research on uses of online media in science has explored how the boundaries between these spheres are breaking down, as previously private spaces are open to public access. These developments may make the timing of this publication ironic or fortuitous – we can present this collection as a summation of the knowledge accumulated over several decades of a phenomenon that is now going through significant changes.

We will return to what this collection tells us about the state of the art when we review the four sections but, first, we need to address the always-vexed question of how we selected the material for this collection. We started with some fairly roughly drawn criteria, and as we proceeded, we refined and revised them. We also balanced them against each other. Thus, for example, as the frequent use in our field of a given paper or chapter favoured its inclusion, the criterion of explicit attention to communication ruled it out. In summary, we hope to have assembled a collection of texts treating science communication in various ways that

- have explicitly addressed processes and contexts of communicating science

and/or

- have proven their worth in the field through frequent citation

and/or

- have been cross-referenced in other texts within the collection

and/or

- have been valuable to the editors of this collection in their own work

and/or

- have endured as foundational texts in the field

and/or

- have set new directions for work in the field

and/or

- have the potential, in the editors' view, to influence future work in the field

and/or

- represent significant elements of the diversity of the field

and/or

- address big moments or big issues in the evolution of science communication.

In our initial scoping of the corpus from which we might select, we listed works we have cited ourselves frequently, looked at the bibliographies in those works, and at the bibliographies of papers and chapters such as literature reviews that surveyed the field, all the time adding items to our list. Not surprisingly, certain authors' names came up repeatedly, so we decided in the interests of wider distribution to limit our selection to two works by any one author. (This also applied to co-authorship.) Our long list ran to over 200 items and, through continuing refinement and review, was whittled down to just over one third of that.

We had the opportunity at an international conference to ask several of those authors who were represented to choose the two works they would most like to have included. Again, not surprisingly, they found this a difficult, but also interesting, exercise. We made it clear then, we were not bound by those authors' selections of their own 'best work'.

In applying notions of value and quality to our selection we excluded works that, although frequently cited and influential at least for a certain period, represented in our view blind alleys. Thus, there are no examples here of what was a very common type of science communication analysis, and remains in usage to a lesser degree, namely the study of popular, mainly mass media, texts in terms of their (in)accuracy in scientific terms. It is also the case, however, that we tended not to include empirical studies – whether based on accuracy concepts or others – unless they offered in their set-up or their conclusions substantive contributions to the conceptual understanding of the field.

Related to the exclusion of accuracy studies, the once-dominant 'deficit' model of science communication, also remaining in usage, is present here mainly as an object of critical study. Apart from the highly influential 1985 report of the Royal Society on public understanding of science (chapter 26 in this collection), there are here no mere statements or proposals of the deficit approach to science communication, that is, an approach based primarily on a perceived or assumed deficit of understanding, knowledge or attitude in the target audiences. We make no claim that this collection is representative of the whole field over the last three decades or more; we would like to believe that it does represent good practice.

As readers of several languages ourselves, we found it particularly onerous to be limited to texts in English. We were in a position to commission only one translation, and we are especially happy to include here in its first English-language publication an essay by Jean-Marc Lévy-Leblond, The Case

for Science Criticism (chapter 32). We are all too aware that there are other works in French, but also in German, Spanish, Italian and other languages, that merit consideration and possible inclusion in this anthology.

The bias towards authors writing in English as their native language is mitigated somewhat by the use of English as the *lingua franca* in the field, including by writers with other first languages. Thus, we have authors here whose mother-tongue is Finnish, German, Japanese, Portuguese and other languages. Of course, this dominant position of the English language in international academic publishing produces its own distorting effects that are especially significant when we are writing about writing and talking, but that is a matter for a much wider discussion.

Keenly aware of this and other limitations we observe of this collection that

- USA and Britain together account for nearly two-thirds of total entries, when these are assigned to a country through their lead author's institutional affiliation; but also
- geographic diversity increases over time: seven countries are represented among authors and co-authors of items published before 1995 and 14 countries for items published later;
- gender diversity also improves slightly: women account for one-fifth of authors and co-authors up to 1995, and one-quarter for the period since then. However, works by two women, Rae Goodell (chapter 25) and Dorothy Nelkin (chapter 72) from the 1970s and 1980s, respectively, are highly influential within this collection and, to judge by the cross-referencing, have fully earned the over-used description, seminal.

The threshold of 1995 for internal analysis of the collection is somewhat arbitrary, though it is in the early and mid-1990s that education, research, publishing and conferencing in science communication take a leap forward. In this period, postgraduate (Diploma and Masters) programmes are established in several countries and PhD projects in the field assume critical mass. The two still-dominant academic journals, *Public Understanding of Science* and *Science Communication* are, respectively, launched and renamed in this period too.

As well as reflecting in a small way what we have called elsewhere the global spread of science communication (Trench et al 2014), the increasing geographic diversity also indicates the increase in multi-authorship and in cross-country studies, both important trends in the development of our field. The very clear domination of single-author pieces in the years up to 1995 recalls that science communication was addressed very largely by individual champions and advocates for the topic. Multi-authorship can be taken at least in some part to show the increasing institutionalisation of science communication; collaborations between scholars often arise from connections between institutions in shared projects, including cross-country studies.

Disciplinary and professional diversity also increases somewhat, when items are assigned an affiliation based on the lead author's background. Up to 1995, social scientists are clearly dominant, as lead authors of half of all items, compared with just under one third for communication studies, and

one in seven for natural sciences. From 1995, the balance shifts slightly towards communication studies (just over one third), though social sciences are still the most strongly represented, with two-fifths. The chapters that originated as papers in STS (science, technology and society) journals come with a single exception from pre-1995; in the total collection, the field-specific journal, *Public Understanding of Science*, alone accounts for more than those several STS journals together.

The distribution of our selections to the two periods, with two-fifths in sixty years before 1995, and three-fifths in twenty years after that, can be taken as reflecting the increased publishing activity, but also, undoubtedly, a recency bias on our part. Our assessment of the significance of some items published in the last decade may well prove ill-founded. However, it should be noted that several of these items are by authors well-established in the earlier period.

At the other end of the scale, there are papers and essays here that can be considered classics, that have been mined and mined again and proven their worth over many years. Italo Calvino once defined a classic as a contribution "that has never finished to say what it has to say". He was referring to classics in literature, but his definition may well apply also to some of the texts collected here. Indeed, one path of entry into this collection is through reappraisal of the enduring value of several 'foundational' texts. Despite relevant changes in media technologies, organisational logics and professional practices, transformations of the public as well as attitudes to communication by scientists, some of the key theoretical questions today are still strikingly similar to those raised by authors such as Fleck, Merton and Medawar: What is the relationship between science communication addressed to non-specialists and the core, specialized practices of scientific communication? What are the dynamics of visibility and recognition both within the scientific community and in society at large? How do communication contexts shape expository practices in science? Does exposure to media coverage (and its tone) influence public perception and attitudes to emerging science issues – and more in general, to science?

This suggested reappraisal, however, might also be seen as testifying a certain reluctance within the field to build upon its own foundations. In contributions here from twenty and thirty years ago, we find careful unpicking of the assumptions underlying then-emerging policies and practices based on hierarchical models yet we commonly witness in conferences or meetings and even specialised journals, debates that seem to repeat those assumptions and arguments and largely ignoring classic contributions. Paternalist models of communication that have been repeatedly proved invalid (or at least valid only in limited, specific situations) in the critical literature are commonly recycled in an unproblematic fashion, at least in advocacy and discussion that is close to practice and policy. The wheel of science communication has thus been and still is often re-invented.

Why then are these classics and their lessons so often forgotten? Multiple reasons may converge to account for this phenomenon. Studies and discussions of science communication have developed in many regions of the world, at least in an initial phase, from practical concerns of different categories of actors (raising public awareness and support of science, improving journalism practices, making

research results and institutions more visible and recognised) and with rather weak connections to social science research. Scholarly journals dedicated to theoretical discussion and empirical research have appeared later than general discussions, resource mobilisation and practical initiatives. This may also account for a continuing trend in the field that sees a rather weak representation of theoretical contributions, even in comparison to empirical studies.

Neglect of classics may also be a consequence of the fact that science communication as a research field developed through the intersection and contribution of different disciplinary areas – media studies, sociology, social psychology, linguistics, science and technology studies and many others. But – as Calvino also suggested – classical contributions and classical themes should not just be an opportunity to look backwards. They are also valuable resources to face contemporary and future challenges in the field. Many of the readings in this collection could be used to expand and deepen a lexicon of the most common keywords that we put together (Bucchi and Trench 2014), thus exploring how different authors have contributed to defining and articulating such concepts. Classical contributions could also provide fruitful insights to understand challenges that arise in connection with the broad process of co-evolution of science, society and communication media. We see these challenges to science communication studies as falling under five main headings[1]:

- *Increasing fragmentation of actors, publics and media*. Science institutions and actors are diversifying their attitudes and practices, also in the communication domain, making it decreasingly valid to continue using traditional expressions like "scientific community" that imply internal homogeneity and a shared commitment to specific norms and values (Bucchi 2009). Equally importantly, the plural 'publics' of science communication need to be acknowledged. It was already a significant achievement in this field to adopt the plural term. But the publics continue to multiply and fragment, not least through the fracturing of media and emergence of new platforms.

  In considering particularly the 'publics' part of this topic area, the more recent contributions included here from Godin and Gingras (chapter 50), Priest (chapter 63) and Einsiedel (chapter 64) but also the historical overviews of Goldsmith (chapter 50) and Shapin (chapter 51) may be especially useful.
- *New mediations*. Digital media allow, among other things, research institutions and actors to supply directly to target audiences an unprecedented amount and variety of materials, e.g. videos, interviews with scientists, news items. In the broader context of ever-stronger public relations efforts by research institutions, this contributes to what has been called 'the crisis of mediators' – the once-indispensable intermediaries (science journalists, in this case) are increasingly displaced or marginalised. In the same way, traditional media platforms for science communication like newspapers, magazines, television and radio programmes and

[1] The following section is drawn in part from Bucchi and Trench (2014)

science museums and centres, are losing their role as filters and guarantors of the quality of information. These developments make evaluation of science communication processes and products an ever-more pressing issue; the criteria and indicators for evaluation need discussion too.

In this collection, contributions from Weingart (chapter 21) and Fahy and Nisbet (chapter 46) offer valuable pointers to understanding these shifts within and between institutions and media.

- *Collapsing communication contexts*. The traditional sequence of the communicative process – specialist discussion/didactic exposition/public communication or "popularisation" – has been fundamentally disrupted. Public exposition of science is no longer a static page written by the winners in the struggle to establish a new scientific paradigm (cf. Kuhn 1962). More and more, the analysis of public communication is required to consider how and by whom the substance and the mode of such communication are determined in exchanges within and between sciences.

  Over twenty years ago, Phillips and colleagues (chapter 29) and Lewenstein (chapter 31) set out some ways in which communication circuits and contexts were intersecting each other.
- *Science in Society and Science in Culture*. The first of these phrases has come to be used as a handle for policy programmes. As a means of conceptualising relations it represents an advance on 'science and society', but situating science in society and culture implies much more than improved functionality. We may usefully redefine the object of science communication research as 'How Society Talks About Science' and this implies researching the cultural contexts – scientific, artistic, everyday, and other – of such talk. Researchers need to explore with more courage conceptual affinities and potential inspiration in the humanities, arts and culture, largely neglected by science communication scholars, despite the growing science/art practice. For example, concepts such as 'style' may be relevant to understanding variety in science communication as well as addressing the challenge of quality (Bucchi 2013). This resonates with long-standing invitations to "put science into culture" (Lévy-Leblond 1996), emphasising its connections with other domains rather than its separation from society and culture, as expressed in notions of knowledge translation and transfer. It also invites us to recognise the importance of a broader culture of science in society that goes beyond familiarity with technical contents to include an awareness of its role, implications, aims, potentialities and limits. It eventually demands that not only society, the public and culture are problematised in their relationship with science, but that science problematises its own cultural premises. In this way, science communication – both practice and research – can contribute to increased reflexivity within society and within science.

  Among the works collected here, Snow (chapter 2) and Goldsmith (chapter 50), commenting on Snow, deserve renewed attention, viewed more comprehensively than the simple citing of

"two cultures" allows. Lévy-Leblond (chapter 32) argues importantly that criticism of science is a vital function in putting science into culture.

- *Global trends and challenges*. Public communication of science has become a global enterprise with common denominators as well as distinctive regional characterisations (see Trench et al 2014). This certainly expands opportunities for experimenting with communication formats and for comparative analysis of, for example, the application of similar approaches in different contexts. It also makes increasingly visible the strong contextual interaction of science communication patterns with broader cultural, policy and socio-political landscapes.

  As the science museum or science centre becomes one of the primary vehicles of this global spread, the history of these institutions, as told and contextualised by Schiele (chapter 47), may be especially useful. Taking the increasing diversity of social contexts into account, the discussion of models of science communication – see, for example Horst (chapter 19) and Trench (chapter 20) – needs constant renewal and refinement.

We hope readers find inspirations in many other works in this collection for thinking about the above (and other) challenges: they present theories whose validity should be tested in the face of recent transformations but also concepts that need to be radically rethought. As further guidance to the user of this collection, we summarise the recurrent themes and connections within the four broadly defined sections. It will be recognised that the allocation of individual items to one section or another cannot be precise.

Volume 1: Theories and Models

In the first volume, we include works that have contributed to defining the field of practice and theory through naming and defining critical concepts, exploring key relationships, and elaborating the means to comprehend underlying assumptions. This volume opens with works that are considered classics in terms of their contribution to the broader study of science in its social contexts, before giving an overview of some of the most influential theoretical contributions specific to the field.

Ludwik Fleck's extract selected here is typical of the first type. Originally published in 1935 and then largely forgotten, Fleck's work was substantially reappraised after Kuhn (1962) acknowledged drawing inspiration from it for his highly influential book, *The Structure of Scientific Revolutions*. Outlining his own vision of social and cultural processes embedding science knowledge, Fleck attributes high importance to communicative exchanges between different social contexts as well as to the role of popular communication in shaping scientific ideas; in this, he surprisingly anticipated more contemporary conceptualisations.

Weak and troubled exchanges among different areas of culture and professional cultures were at the core of C.P. Snow's famous 1959 lectures on the *Two Cultures*, of which we include the first (chapter

2). Snow's contribution has frequently been (mis-)used to argue and campaign for injection of more 'scientific culture' in society – 'culture' being here mostly intended in the rather narrow sense of competence or literacy.

Gieryn's classical piece on boundary work (chapter 5) provides a useful companion in this respect, by tracing the genealogy of professional demarcation strategies and their key rhetorical tools in establishing scientists' social and cultural role. The shaping itself of a "scientific fact" is analysed by Latour (chapter 7) as a painstaking process that requires the support and cooperation of a complex network of 'allies' (colleagues principally, but also texts, visualisation, machinery) both within and outside the laboratory, in order to become established or "ready-made" science for unproblematic use both by experts and non-experts. Although Latour's work was originally mainly concerned with core scientific practice, over the years it has been influential also for studies of public communication of science.

Another classic and highly influential work comes from the recognised founder of sociology of science, Robert K Merton (chapter 3). His theorisation of the dynamics of visibility and recognition of scientists through the 'Matthew effect' drew attention to the marked inequality in the distribution of these resources across the community of researchers. The tendency to self-reinforcement in these resources (visibility brings more opportunities for further visibility and recognition) became even clearer to scholars in the following decades, when communication with the public and closeness to the media became increasingly relevant for scientists and their institutions. In this connection, we note Goodell's seminal contribution on 'visible scientists' (chapter 25), in the next volume, and Weingart's early allusion to 'medialization' of science (chapter 20). Nowadays, "celebrity scientists" - meaning visible scientists turned into all-round public figures and media stars (physicist Stephen Hawking being a prime example) - are a familiar phenomenon both to media audiences and science communication scholars. These celebrity scientists are assessed in a recent publication by one of the contributors to the present collection (Fahy 2015).

From the mid-1980s, scholars from the social sciences or drawing on social studies of science addressed critically the traditional conceptions of public communication of science. The critiques of this approach as a 'deficit model' (e.g. Wynne, chapter 11) are commonly recalled and repeated. But other probing and prescient critiques from the 1980s and 1990s, such as those of Trachtman (chapter 4), Cloitre and Shinn (chapter 6), Dornan (chapter 8), Hilgartner (chapter 10), Michael (chapter 12) and Bucchi (chapter 15), deserve continuing attention. These contributions have highlighted, among other things: the non-linearity of the communication process; the reception of science communication not as a passive process but a complex set of active transformative processes which can, in turn, have an impact on the core scientific debate itself; the difficulty of sharply separating specialist exposition of science theories and results from popular exposition, despite the fact that distinctions between the two forms of exposition are often used by scientific actors as a rhetorical strategy (to criticise or exclude colleagues from scientific debate, for example); science communication processes being

better described as a continuous sequence of expository levels, gradually shifting one into another with differences in degree, mutually influencing one another.

Concrete examples have been used to propose rethinking the widespread yet rather simplistic notion of science communication as 'physical transfer' of ideas and notions from the experts to the public, with public discourse mostly portrayed as a filtered or trickled-down version of specialist discourse (see Bucchi, chapter 18). Other contributions in this collection, particularly by French scholars, explore the narratives and ideologies supporting traditional visions of science's role in society and culture (e.g. Lévy Leblond, chapter 13; Jurdant, chapter 14). Lievrouw (chapter 9) draws on social representations theory first developed in France to suggest a more fully contextualised understanding of public communication of science.

During more recent decades, the development of intellectual debate and changing dynamics in the very relationships between science and society – enduring public concern over certain science and technology issues despite significant communication efforts, growing citizen demand for involvement in such issues, increasing sensitivity of scientists and their institutions to media logic – led to the emergence of new keywords: *dialogue, engagement, participation, mediatisation* (Miller, chapter 17; Weingart, chapters 16 and 21). Reflexive assessment of the more or less implicit models of science-and-public interactions embedded in these keywords (including those stigmatised as encapsulating hierarchical visions, like *deficit*) and their understanding in terms of potential co-existence rather than evolutionary sequence or competition characterise some of the more recent contributions collected here (Horst, chapter 19; Trench, chapter 20; Irwin, chapter 22).

It is worth drawing attention here to one particular absence in this collection. The report from the House of Lords (2000) in Britain is often mentioned, well beyond its country of origin, as a milestone in the supposed trajectory from deficit to dialogue. A single phrase from that report, referring to "the mood for dialogue" that the Lords detected, recurs repeatedly, frequently without adequate indication of its context. It might be expected that this report would find its place here, allowing that context to be seen. But the report is that of a parliamentary committee which hosted briefings from various experts and practitioners; it is replete with references to the evidence of individuals and organisations heard by the committee and any extended excerpt would require many explanations and footnotes to make it comprehensible. That emblematic phrase, "mood for dialogue", will have to continue to stand for the report as a whole. The impact of the Lords report is considered by Miller (chapter 17) and Irwin (chapter 22) in their discussions of changing policies and approaches

Volume 2: Processes and Practices

In this volume we present works that analyse routines, strategies and relationships in science communication and science reporting for media, that advocate policies, or that present the experiences, reflections and advice of science popularisers of various kinds.

In Peters' very influential survey-based analysis of the relationships between the cultures of research and of media (chapter 33), there is also a third cultural dimension, that of the everyday. But in this paper and in several others, the main emphasis is on the negotiation between the professional cultures of science and media around the authority of science and the meaning of particular developments in science. Wilkie (chapter 35) and Radford (chapter 36) describe this negotiation from the perspective of the science journalist, seeking to make sense of scientists' claims-making and to turn pieces of scientific information into stories. Here, and in the reported views of science journalists that Hansen interviewed (chapter 30), the relationships are described mainly as tense, even antagonistic.

In broader sociological analysis, Dunwoody (chapter 38) notes the success of "the scientific culture" in securing "interpretive control" of popular science and science in the media, while Goodell (chapter 27) describes as "chauvinism" the notion that "the views of scientists on scientific issues are definitive", noting that science reporters also subscribe to this "chauvinist" notion. This is the basis of the "shared culture" that Dunwoody observes between scientists and journalists specialising in science. This view of close relations is also represented in the recurrence of a specific word, "symbiosis" or "symbiotic", in Goodell (chapter 27), Allan (chapter 44) and Peters et al (chapter 43). The same term is also found in LaFollette (chapter 66), in a text included in the later volume on media representations.

The literature might thus appear to point in two directions when stressing the differences, on the one hand, or the commonalities, on the other hand, between professional cultures. In part, this is a matter of historical development: over the period covered by this collection, the professional culture of science has been increasingly affected by the orientation to media and to the public. Goodell (chapter 25) is one of the earliest to describe this orientation, and the comparison between two works here by Peters as single author (chapter 33) and lead author (chapter 43) offers some insight into how that orientation progressively took effect. In part, the apparent contradiction is also a matter of geography and of communities within science – the professional culture of science is changing in different ways in different countries and in different disciplinary communities (see, again, Peters et al, chapter 43) – and of communities in journalism.

The professional culture and practices of science journalism are being influenced by the changing media environment, as explored here in more recent works by Allan (chapter 44), Trench (chapter 45) and Fahy and Nisbet (chapter 46). They add to Lewenstein's detailed account (chapter 31) of increasingly complex webs of communication, all emphasising the impacts of technological change. However, in his survey of the phases of evolution of science museums and science centres, Schiele (chapter 47) emphasises technological less than societal shifts; these are reshaping science as an object of exhibition and redefining museums as institutions and social actors.

It was through an often-cited case study of museum professionals, that Star and Griesemer (chapter 28) earlier developed concepts of boundary objects and boundary work in reference to communicating science. Boundaries are often either implicitly or explicitly at issue in chapters throughout this volume

and the collection as a whole: Lewenstein's analysis draws attention to the interpenetration of professional and public communication, as do Phillips et al (chapter 29) and Kiernan (chapter 42) in his update and deepening of Phillips and colleagues' study; these studies show how mention of a scientific paper in the New York Times increases its likelihood of citation in the scientific literature. Despite the many technological, organisational and societal changes, the advice from Haldane (chapter 23) on writing popular science still stands in large part; this biologist's insistence on keeping the audience in mind has to be restated repeatedly over 70 years later. The same respect for the audience is there too in Sagan's reflection (chapter 34) on his popularisation activities, in which he advises that scientists should remember how they learned, and should not fear to chronicle the false starts. Fellow-scientist Medawar (chapter 24) considered the failure to mention false starts when formally communicating scientific work with peers as tantamount to "fraud". Gould (chapter 39) offers personal and critical insight into how scientists conventionally construct science for public consumption and how he learned from wider cultural experience to do this in more fulfilling ways. As previously mentioned, scientist Lévy-Leblond (chapter 32) takes the broader cultural view in making the case for criticism of science itself, akin to art criticism, as an essential part of science's cultural embedding. We are pleased to present for the first time in English translation this essay by a commentator on science who deserves greater global recognition.

Insightful and sometimes ironic reflections by scientists as popularisers or commentators stand in contrast with the more didactic approach of one of the world's oldest scientific institutions, the Royal Society, in its policy and strategy report (chapter 26) on public understanding of science. This report, from which we publish extracts, represented a landmark in Britain and beyond, as did the report of the House of Lords 15 years later.

The strategies of scientists and science-based industries are explored in case studies by Goodell (chapter 27) and Priest (chapter 41), around issues in biotechnology, and by Gregory and Miller (chapter 37), around food risks and possible collisions with comets. Underlying these studies, and made explicit by Gregory and Miller, is a concern with equity in communication. These authors echo Haldane (chapter 23) when he urged scientists not to write as if for "an audience of fools", and to recognise the need "to educate yourself as well as your public". Priest, like Gregory and Miller, insists on the need for communication in the kind of circumstances described to be two-way, thus bringing us back to the consideration of models in the previous volume.

Volume 3: Publics for Science

This volume presents analyses of audiences of science communication, their transformations and their interactions with scientific experts. Reflections on, and empirical studies of, the public have been an enduring concern in the field and often also the object of controversial discussion among scholars.

Shapin (chapter 51) provides an historical overview that helps us understand the theme of science publics in the context of broad transformations in the social role of science and its communication patterns. Shapin's contribution usefully reminds us that public communication and public interest in science did not start with the emergence of mass media. Bensaudé-Vincent (chapter 58) also offers an historical summary of the emergence of the public for science – and changing views of that public from within science – before focusing on the case of 20th century physics, and how its development contributed to a perception that the gap was widening between science and the public.

This contribution insists on the complexity of "the public" and controversy in this area of research and reflection has often centred on conceptions of scientific literacy, and their lack of appropriate complexity. Early studies of public perceptions and attitudes to science had a strong – when not dominant – focus on lay knowledge of scientific facts (Miller, chapter 49); this emphasis was later substantially criticised as too narrow and lacking attention to other dimensions of public relationship with science. Such critiques have proposed rethinking and expanding notions such as "scientific culture" beyond the issue of competence and factual understanding of science (Goldsmith, chapter 50). Part of this reframing of questions about the public has involved proposals for refinement of public attitude surveys and deeper, more thoroughly contextualised analysis of their findings (Godin and Gingras, chapter 57; Bauer et al, chapter 61).

In an early contribution, Durant (chapter 53) questioned the concept of scientific literacy, suggesting it was not limited to knowledge of scientific content but encompassed familiarity with the operational rules and organisational routines of science as well; these were to be seen not just as theorised by epistemology but also in terms of actual and sometimes contingent practices. Since the mid-1990s, in particular (see Evans and Durant, chapter 54), an element of previous studies and policies that came under critical scrutiny was the relationship between knowledge and attitudes. There had been a tendency to assume that understanding of science content guaranteed a favourable attitude towards science actors, institutions and implications – and vice versa, that a lack of understanding bred hostility and scepticism. It has been pointed out that the equation between public understanding and the ability to answer questions about science has long restricted the discussion to the somewhat tautological observation that members of the public do not reason in the same way as professional scientists. Also disputed is the assumed linkage between exposure to science in the media, level of knowledge, and a favourable attitude toward research and its applications.

In relation to emerging or morally controversial areas of science, for example, research has shown a substantial degree of scepticism and suspicion even – and specifically – among the sections of the population most exposed to scientific information. It has also been noted that singular 'science' may be a too broad label to account for the varieties of public engagement with the increasing diversity of research fields, particularly when it comes to newly emerging interdisciplinary areas such as biotechnology or nanotechnology (Scheufele and Lewenstein, chapter 60).

More generally, the disjunction between expert and lay knowledge cannot be reduced to a mere information gap between experts and the general public as envisaged by the deficit model. Nowotny (chapter 48) introduces the volume by offering reflections on the relationship between experts and their public that are still relevant over thirty years later. Lay knowledge is not an impoverished or quantitatively inferior version of expert knowledge; it is qualitatively different. Factual information is only one ingredient of lay knowledge, in which it interweaves with other elements (value judgments, trust in the scientific institutions, the person's perception of his or her ability to put scientific knowledge to practical use) to form a complex corpus (Wynne, chapter 52).

Another challenge to traditional approaches to publics of science came from contributions highlighting the potentially increasingly active and relevant role of non-experts (patients and their families, community groups, citizens) in the shaping of research priorities and processes, particularly in fields like biomedicine, where Epstein (chapter 55) explored the contribution of AIDS activist groups to the development of the research agenda. Callon (chapter 56) derives from such studies three models of the role of lay publics in science, including that of co-production of knowledge, especially relevant to the circumstances Epstein described. Felt and Fochler (chapter 62) sought to apply various models of participation in a practical "collective experiment" around social and ethical issues in genome research. From the point of view of experts and policy-makers, the more strongly participatory possibilities and practices represent what Jasanoff (chapter 59) memorably called "technologies of humility", proposed as a counter-weight to the "technologies of hubris" that define technocratic policy-making. Jasanoff's contribution links strongly with that of Irwin in volume 1 (chapter 22) where he proposes a "third-order" approach to policy-making and public participation around risk.

Increasingly, "the public" for science has come to be seen as diverse, differentiated, and plural, hence the frequent use of "the publics". Priest (chapter 63) describes the range of "diverse audiences" for media science, and Einsiedel (chapter 64) charts the proliferation of forms of public engagement and participation, returning to the preoccupations of many contributions in this volume with the shifting configurations of science in society.

Volume 4: Media Representations of Science

This volume includes analyses of story-telling and representations of science in public affairs media. These are not only content studies of one kind or another, but also examinations of the production of content and, in a few cases, its reception or public impact. The commentaries and analyses address coverage of science in newspapers, magazines and television. We acknowledge that this section and the collection as a whole do not address popular-science books or representations of science in fictional media. Both of these are niches with some well-established exponents but such works have not generally had wide resonance in the broader field of science communication studies. The absence

of any consideration of science on radio, on the other hand, reflects the very weak attention paid in our field to this medium, which has a long history and a strong presence in the public communication of science.

Of the 15 works in this section, five treat science on television, and ten address science in print media, mainly elite (or 'quality') newspapers or magazines, but these studies are also differentiated by their methods or conceptual tools, whatever the medium addressed. Science sociologist Collins (chapter 68) expressly distances himself from the communication studies approach of Silverstone (chapter 67), though both are examining programmes in the long-running BBC television documentary series, *Horizon*, and concerned, from their different perspectives, with understanding the process by which television constructs science for public consumption. Silverstone draws mainly on formalist studies of narrative, while Collins considers how laboratory processes are represented.

LaFollette (chapter 66) observes the strong influence of scientists in television's construction of science, referring here to "symbiotic dependence" and claiming that, on television, "the scientist alone – not the science commentator, or critic – speaks for science". This is also a primary concern of Nelkin (chapter 72) in an extract from her book, *Selling Science* (1987/1995). This book or closely related work by Nelkin is cited in a majority of the works in this section and by many more throughout this collection. *Selling Science* fully merits the designation of "classic", though there is some validity to Bauer et al's (chapter 77) description of it as "somewhat anecdotal, but poignant". In the extract from *Selling Science* included here, Nelkin observes that the media convey "the mystique of science as a superior culture", creating a distance between scientists and the public. She shows the media as too-receptive to the "handy phrases" offered by sociobiology to explain human behaviour. Mazur (chapter 65) also referred in an earlier study to the case of sociobiology, but drew attention to the media's role in stoking controversy about that emerging field of science, as well as about nuclear power and fluoridation of water supplies. Mazur sought to discern the impact of such media coverage on shifts in public opinion, while several other works here stress the importance of considering the audience's perspective in the making of media products. For their part, De Cheveigné and Véron (chapter 73) study directly French television audience responses to science programmes, deriving from these responses four public perspectives on science.

Examining Finnish television representations of genetics and biomedical research, Valiverronen (chapter 76) proposes that scientists are seen here in five public roles. One these is the hero role, and Silverstone (chapter 67) had earlier seen television representations of scientists in the roles of thinker, technician, labourer, demonstrator, interpreter, which he describes as "different aspects of the hero". Felt (chapter 71) defines the presence of hero scientists as one of the major ingredients in the "scientific success stories" on superconductivity that she analyses in the German-speaking and US press. Jacobi and Schiele (chapter 69) finish on the same theme in their analysis of images of scientists in popular science magazines. Through photographs, they write, the magazines anchor

knowledge in the laboratory, "And what better means of relaying this than science heroes surprised at the moment of their triumph over ignorance?"

Images and stories, metaphors and frames are central to several contributions here. Nelkin (chapter 71) explores as "promotional metaphors" the favoured narratives and images in the coverage of genetic research. Nerlich and colleagues (chapter 75) apply discourse and metaphor analysis in their study of UK press coverage of the 2000 announcement of the Human Genome Project's (near-) completion, tracking key phrases repeated across their sample and concluding that "metaphors can be double-edged". Also using discourse analysis, Carvalho (chapter 78) shows shifts in emphasis in the UK press's coverage of climate change; these differences between three newspapers and the shifts over time are linked to the individual newspapers' ideological standpoints.

In a wide-ranging analysis of US press coverage of biotechnology, Nisbet and Lewenstein (chapter 74) apply a typology of frames adapted from Durant et al (1998). It is notable that the several uses of framing in the works here are rather different one from the other; Nisbet and Lewenstein are undoubtedly right to draw attention to the issue of measuring latent content reliably. In Bauer et al (chapter 77), framing is said to refer "to the way a story is told by unfolding arguments, using metaphors and imagery that define a problem, arriving at causal or moral attributions, and prescribing particular remedies". However, Schäfer (chapter 79) in his study of German media coverage of neutrinos, the Human Genome Project and stem cell research applies frame analysis in a different way, as he aims to operationalise and test the medialisation-of-science theory first mentioned by Weingart (chapter 16) and further developed by him (chapter 21) and others, particularly in the German-speaking and Nordic research communities. Schäfer finds the theory stands up in relation to some spheres of science but not in relation to others. This final chapter usefully points the way both for further empirical studies and for further theoretical studies.

It is in the continuing dialectic of reflective practice, empirical studies and theoretical analysis that we can hope to see further development of this always intriguing and shifting field.

References

Bucchi, M. (2009) Beyond Technocracy. Citizens, Politics, Technoscience, New York: Springer.

Bucchi, M. (2013) Style in science communication, *Public Understanding of Science*, 22, 8: 904-915

Bucchi, M. and B. Trench (2014) Science communication research: themes and challenges, in M. Bucchi. and B. Trench (eds) *Routledge Handbook of Public Communication of Science and Technology*, 2nd edition, London: Routledge, 1-14

Durant, J., M. Bauer, and G. Gaskell (eds) (1998) *Biotechnology in the public sphere: A European source book*, London: Science Museum

Fahy, D. (2015) *The New Celebrity Scientists: out of the lab and into the limelight*, Lanham, MD: Rowman and Littlefield

Kuhn, T. S. (1962) *The Structure of Scientific Revolutions*, Chicago: University of Chicago Press

Levy-Leblond, J. M. (1996) *La Pierre de Touche: la science à l'épreuve*, Paris: Gallimard

Trench, B. et al (2014) The global spread of science communication, in M. Bucchi and B. Trench (eds) *Routledge Handbook of Public Communication of Science and Technology*,2nd edition, London: Routledge, 214-230