Internet - turning science communication inside-out?

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In the four decades since two university computers were first linked to each other over the prototype internet, scientific researchers have been innovators, early adopters and prolific adapters of internet technologies. Electronic mail, file transfer protocol, telnet, Gopher and the World Wide Web were all developed and applied first in research communities. The Web's development for sharing of information in the high-energy physics community unexpectedly heralded the internet's extension into many aspects of commerce, community, entertainment and governance. But despite the rapid proliferation and diversification of both over the past 15 years, the internet in its various forms has scientific communication indelibly inscribed into its fabric, and internet communication is thoroughly integrated into the practice of science.

This chapter reviews some effects of the internet's emergence as a principal means of professional scientific communication, and of public communication of science and technology. It notes several paradoxes that characterise these developments, for example the contradictory trends towards easier collaboration across continents, and towards greater fragmentation. It notes the very significant disturbances caused by electronic publishing in the all-important field of scientific journals. It suggests that these and other developments have made more completely porous than before the boundaries between professional and public communication, facilitating public access to previously private spaces, and thus 'turning science communication inside-out'.

At home in the internet

Already, a decade ago, it could be claimed that 'it is now difficult for scientists to remember how they worked without the internet' (Rowland 1998). Scientists are socialised into a world in which communication via the internet is 'natural'. Communication is the engine of science, accounting for an increasing amount of scientists' time and increasingly taking place over the internet. From posting calls for research proposals on the Web, through conferring with partners on a proposal by email, to the joint production, online submission and online review of the proposal via email and attachments, and on to the confirmation of the decision on the proposal, research projects or programmes can be - and are - established over the internet, without a face-to-face meeting or any paper changing hands. Very many of the routine activities of scientists are facilitated over the internet: calls for papers, editing of journals, hosting of conferences, sharing of data, authoring of papers, publication of conference proceedings and journals, and many more informal exchanges and encounters.

The processes by which the internet has come to fill this central place in internal scientific communication demonstrate well how technological innovations can be shaped socially to forms and functions not anticipated by the originators and first adopters. These processes have also been paradoxical in many ways: the internet facilitates collaboration between researchers on an effectively global scale across cultural, geographical and disciplinary boundaries; the internet also brings with it accelerated specialisation or 'balkanisation' within the sciences (Van Alstyne and Brynjolfsson 1996), as a sub-specialist who may be one of a kind in her own face-to-face community can interact with someone else in the same sub-specialism in any other part of the world. The internet operates as a means of collaboration, but also to facilitate and foster intensified competition, between institutions presenting their achievements over the Web, between discipline niches networking by email, and between individuals arguing in online discussion groups.

More important, in the context of public communication of science and technology, are the impacts — many of them also somewhat paradoxical — of the development of internet-based media on the dissemination of scientific information beyond the research communities. These media include versions of science news services already provided via print and broadcast, and 'net-native' services with their origins and their only manifestation in the internet environment. They cover promotional activities by research and educational institutions aimed at policy-makers and commercial partners, and public education initiatives by charities and science museums. Alongside research reports of new findings are other reports contesting or confirming those findings. Professional societies, research flinders, higher education institutions, commercial companies, groups promoting science, groups challenging science, and many other interests are all active in amplifying or questioning information about science over the internet.

In enumerating these actors, we glide from internal scientific communication to public science communication, and it is here that we observe the most significant, and again most paradoxical, effects of the internet on science communication -principally the accelerated erosion of boundaries between previously distinct spheres of communication. While some science communication scholars have drawn attention to the long-time interpenetration of public and professional spheres (Lewenstein 1995; Bucchi 1998) and to the role of popularisation within science (Gregory and Miller 1998), these overlaps have become more tangible through the proliferation of Web-based science communication media.

'Access to the Web has opened up many aspects of scientific research previously hidden from the general public,' it has been claimed (Peterson 2001). Members of interested, but non-specialist, publics have access to information prepared by professional organisations primarily for consumption by professionals. Parts or all of sites maintained by scholarly societies and scientific journals are open-access, or require only that users register by name, opening internal discussions, pre-publication thoughts and professionals' agendas to wider public view. If, in some sense, the presentation of scientific information by scientists to the general public may be regarded as a performance, we can say - recalling sociologist Erving Goffman’s terms - that,

through the internet, some of the back-stage preparation has become visible to the prospective spectators of the front-stage performance (Goffman 1959).

Open access: for whom?

One means by which this happens is open-access publishing of journals and papers. This is one of the most far-reaching developments in professional scientific communication based on the internet. It is also one with significant implications for public communication of science and technology. Open-access publishing over the internet predates the development of the Web; one of the best known initiatives in this field, the Los Alamos Physics Papers (www.arxiv.org), was established in 1991. Despite several generations of technological change and interface design on the internet since then, the site retains its original look and feel. Here, papers are published electronically before formal review, or in parallel with their publication in a conventional journal. Any Web-user can access scholarly papers on particle accelerators, solar energy or cosmic rays — although, of course, not every Web-user can make sense of them.

This initiative, and similar ones, may be seen as an application of the 'communalist' norm that Merton (1942) identified over 60 years ago, although with enduring impact, as operating in scientific communities. The Human Genome Project's commitment to publish chromosome sequences as they were completed represented an application of that principle. Indeed, that project was impracticable without the internet; it was a computer and telecommunications software project as well as one in biological sciences. Sharing new information among scientists as widely as possible has found an appropriate, cost-effective platform and a means of effective realisation. The International HapMap Project, a successor to the Human Genome Project, started in 2002 to 'compare the genetic sequences of different individuals to identify chromosomal regions where genetic variants are shared'. In 2004, it removed its licensing regime to prevent potential commercialisation of its work: 'All of the consortium's data are now completely available to the public' over the internet (International HapMap Project 2004).

But the application of internet technologies has not been exclusively in the direction of communalism. The field of scholarly publishing in general, and scientific publishing in particular has been in ferment for over a decade, as the small number of large-scale commercial journal publishers, on the one hand, seek to extract more value from their franchises through electronic publishing and database services, and professional societies, higher education institutions and their libraries, on the other hand, seek to apply the newer technologies to reducing the costs of sharing scientific information. That battle is still joined, but we can at least say that there is, as yet, no confirmation of Winston's 'law of the suppression of radical potential' of new communications technologies (Winston 1998).[i]

The internet's impact in this arena is keenly felt. The Berlin Declaration on Open Access to Knowledge in the Sciences and Humanities, initiated in 2003, begins:

> The internet has fundamentally changed the practical and economic realities of distributing scientific knowledge and cultural heritage. For the first time ever, the internet now offers the chance to constitute a global and interactive representation of human knowledge, including cultural heritage and the guarantee of worldwide access.
>
> (Berlin Declaration 2003)

The Declaration aims 'to promote the internet as a functional instrument for a global scientific knowledge base'. By early 2008, the directors or presidents of 250 research centres, universities and other institutions in 30 countries, mainly in Europe, had signed the declaration, and the collection of signatures was continuing. And this is just one of several such high-level international statements making a formal commitment to foster sharing of knowledge through internet-based publishing.

Scientific publishing revolt

These and other initiatives to transform the scientific publishing system and provide wider scholarly and public access to scientific information have been characterised as a 'revolt' (Meek 2001). The development of the internet put the inequity of the established scientific publishing system into sharp relief: 'Trawling computer databases [made] it possible for scientists to discover groundbreaking links between different research results which would previously have taken years of trawling through a jungle of indexes. The prospect of this incredible new tool being controlled by large private corporations has jerked scientists into action' (Meek 2001). Academic and research libraries have been to the fore in these actions, not least because of the large and continuing increases in journal subscription costs. Cornell University in the USA estimated that, between 1986 and 2001. The library budget at its main campus in Ithaca, New York, increased by 149 per cent; the number of periodicals purchased went up five per cent (Anon. 2004). The New York Times observed sympathetically: 'Some subscriptions cost thousands of dollars per year, and those journals are usually available online only to subscribers. This looks less like dissemination than restriction, especially if it is measured against the potential access offered by the internet' (Anon. 2003).

The Scholarly Publishing and Academic Resources Coalition (SPARC) has the backing of universities, research libraries and scholarly societies in seeking to cut journal subscription prices and to make publishers more responsive to customer needs. SPARC is associated with the publication of hundreds of journals in a wide variety of disciplines. One of the earliest was Evolutionary Ecology Research, whose editors moved the journal from a commercial publisher and relaunched it online, in collaboration with SPARC. The first editorial of the new-look journal declared that it wanted to 'maximize the number of scientists, scholars and students who have access to our articles ... [the journal] will be extraordinarily liberal in its dissemination rules' (Rosenzweig 1999). The application of these liberal rules means that much of the journal's content is available to those other than 'scientists, scholars and students', and this journal operates in a field that is contested both within science and within broader publics.

Research and academic libraries have also driven the development of the institutional repository model of networked publishing of papers generated from within their communities; these papers are now shared in a manner that attenuates the journals' control of the material generated from within those institutions. In the late 1990s, the advocacy group Public Library of Science asked researchers to commit to contribute only to journals that agree to place all their material into the public domain within six months of publication, securing tens of thousands of signatures worldwide. By the mid-2000s the impetus had moved to scientific institutions and funders. From October 2005 it became a condition for researchers funded by the Wellcome Trust, a major funder of biomedical science in Britain, that they posted their papers on the life sciences archive PubMed Central within six months of publication.

Public Library of Science (PLoS) has gone on to launch its own journals: PLoS Medicine and PLoS Biology are published, open-access, on the internet. Similarly, BioMed Central publishes over 90 peer-reviewed journals online and free of charge; the publisher derives the income from charges to authors. Even Britain's Royal Society, the world's oldest scientific society, has added an online Biology Letters to its centuries-old Proceedings. Open-access journals represent a very small percentage of all scientific publishing, but the trend has continuing momentum.

Internet users, whether scientists, scholars, students or others, can find such resources through direct access to publishers' sites, or through portal services such as Stanford University's High Wire, Lund University's Directory of Open Access Journals, and PubMed Central, an open archive of literature from the biomedical and life sciences. Thanks to these and related developments, internet search engines include examples such as Google Scholar, which produces results from scientific journals and other forms of scholarly publication. Not merely are such search engines available without restriction to internet users, they are among the most intensively and extensively used facilities of the Web.

Opening formal scientific publication to public view brings with it some interesting challenges, both for scientific communities and for interested publics. For scientists, a key question, keenly contested, is how and whether the traditional standard of peer review should be applied in this changed environment. For Web users, a closely related question is that of the validation and interpretation of information found by hazard or by purposeful searching. It could be claimed, in a previous period, that peer review was the touchstone of scientific validity, and a critical boundary marker or gateway control in a 'continuity model' (Bucchi 1998; Chapter 5 in this volume) of science communication that envisages the arenas of communication as broadening progressively from intradisciplinary, to interdisciplinary, and beyond, to the general public. But the assumed gold standard of peer review has been tarnished by evidence of its misuse to protect entrenched positions and institutions, and by its failure to detect fraud. For Sense About Science, an advocacy group in Britain dedicated to 'an evidence-based approach to scientific issues', peer review remains 'an essential dividing line for judging what is scientific and what is speculation and opinion' (Sense About Science 2005). But even peer review's most ardent defenders have to acknowledge that it is a system

under pressure, due to the proliferation of publishing outlets and the pressures on researchers to maintain certain levels of publishing productivity.

The unique status of peer review is also qualified by the development of internet-based outlets. Some scholars have argued for translation to the internet of the traditional peer review process (Harnad 1996), while others have presented a case for a radically modified 'cyberspace model', in which refereed and non-refereed services coexist (Giles 1996), or a "scholars' forum' as an alternative publishing system (Buck et al. 1999). In 2003, the Royal Society established a working group to study best practice in communicating the results of new scientific research to the public. Among the questions the working group was asked to examine was "what, if any, quality checks or filters should researchers subject their results to before communicating them to the public?' The very question indicates an acceptance that, in a changed communication environment, scientists cannot ensure that all scientific information reaching the public has been internally validated. The working group's deliberations were inconclusive: 'allowing reports of research results to be posted before they have been subjected to the full independent peer review process ... has clearly developed for the benefit of the researchers, [but] little consideration appears to have been given to the consequences of this practice for the public ... the potential for great damage clearly exists' (Royal Society 2006). In similar tone, the working group proposed on the operation of peer review: 'Further debate within the research community about the benefits and disadvantages of referee anonymity is desirable' (Royal Society 2006).

In 2005, three major medical journals — Tlie Lancet, Annals of Internal Medicine and BMJ — opened their operations of peer review to the scrutiny of independent researchers, who examined the processing of over 1000 papers; early results represented a 'qualified thumbs-up to current editorial practices' (Giles 2006). As with the debate on modes of scientific publishing, the debate on the operation of peer review in the changed environment continues to be played out. In a development indicating the impact of the 'revolt' against commercial controls, a new initiative, Partnership for Research Integrity in Science and Medicine (PRISM) was started in the summer of 2007, with the support of the Association of American Publishers, to oppose government interventions favouring open-access publishing, specifically a proposed measure that would require peer-reviewed publications based on government-funded research to be 'surrendered to government. The claimed aim of this coalition is to 'safeguard peer review', which it describes as 'a global standard for more than 400 years' (www.prismcoalition.org).

News for some, or for all?

Electronic publishing has partially opened the spectators' view to the backstage -partially, because only small proportions even of the 'interested publics' (Miller 1988) can use the information made available in this way. But the Web-publishing practices of very many scientific institutions have made access and use even easier. These institutions have adopted a public communication model, that of journalism, in the distribution of information. 'News', or some close equivalent, is a standard feature on websites generally,

and many scientific institutions have adopted a journalism style of presentation to disseminate information about new developments, even where their primary purpose seems to be providing information from professional sources to professional audiences. Increasingly, research centres, scientific societies, research funders, universities and other higher education institutions directly employ science communicators or science writers to provide accessible summaries of research findings and other achievements, mainly via the internet. In this way, the institutions pre-empt, to some extent, the interpretive role of journalists working in the independent media, in a (partial) process of 'disintermediation'. Sharon Dunwoody (Chapter 2 in this volume) draws attention to the effects on science journalism of the 'shift to the internet'. I have written elsewhere (Trench 2007) on the ways in which this shift affects the status and role of journalists reporting science.

The internalisation by institutions of journalism forms can be seen in the websites of, for example, the European Commission's R&D services, the Institute of Physics, the Wellcome Trust and the Royal Society (in Britain), the Max Planck Society (Germany), Centre National de Recherche Scientifique (France) and the National Institutes of Health and the American Physical Society (USA): all have News, Research News, Actualités, Updates or News and Features directly at their home page, or easily accessible from that page. In some cases, the sites offer news alerts or similar services, often drawing on, or linking to, news reports in the general media. These institutions are professional societies, research bodies or research-funding agencies, thus with researchers as their prime public; in the cases of the French and German sites, they offer English-language versions as well as those in their own language, indicating that the global research communities are among their prime public. But these institutions' practices on the Web express further how the boundaries between professional and public communication are eroded, and provide a striking demonstration of a phenomenon that the German social theorist Jürgen Habermas observed over three decades ago in a very different information environment - that scientific communities use general news media to communicate with each other (Habermas 1971).[ii]

Some of the sites maintained by scientific institutions or funders also present the source material on which the news item is based, or link their news reports to the relevant journal papers. Even where the links are not made directly, the more experienced Web-user can trace news media reports back to their proximate sources (press releases) and more remote sources (journal papers), thus laying bare the interpretation and reinterpretation in the processes of public dissemination.

However, the openness shown here is not found in what we might call less mature scientific cultures. In Ireland, a colleague and I surveyed over 100 websites published by scientific institutions, and found they used almost exclusively a one-way model of communication, rarely offering internet users the means to contribute to information and argument (Trench and Delaney 2004). Confirming the findings of comparable surveys in Germany and Poland (Lederbogen and Trebbe 2003; Jaskowska 2004), our study showed that scientific institutions used the Web much more to promote themselves to professional and business

audiences than to share information about their activities with diverse social groups. Facilities for feedback or forum-type discussions were found on just three sites and, of these, one ceased to exist soon after the survey was completed. Applying criteria that reflect widely shared conceptions of internet best practice, we noted that just a quarter identified a particular person for contact purposes, and only one-tenth responded to a message sent to them; half the websites gave contact details for scientists, but just three named individual authors of individual pieces; three-quarters of the websites had a News section, but less than one-third of websites overall dated the posting of their content; three-quarters of the sites had Links sections, and most links indicated were to institutions of the same type as the originating site. Our assessment was that the publishers of these science sites were using the Web mainly to promote themselves to peers, partners and clients and, very much less, to communicate with diverse publics.

Scientific cultures and their associated communication practices may vary widely between institutions and countries, and these findings are not capable of being generalised to broader international arenas. Institutional policies are more-or-less restrictive on their individual members and more-or-less responsive to public contributions. The internet facilitates personal communication as well as formal, institutional communication, and this too is extensively represented in science through the use of newer internet technologies such as weblogs (blogs) to present individual views and facilitate open discussion. The internet facilitates multimedial, affective communication as well as text- or numbers-based dissemination of technical information, and this is represented, for example, in the use of podcasts on some science sites. The leading international scientific journals, Nature and Science, deploy both these facilities on their websites, although the blogs by writers attached to the journals generally take the form of diary notes or informal observations from assignments at major conferences rather than open-ended contributions to discussion, as blogging elsewhere generally tends to be. These websites are the shop-windows of publications and other services offered for sale; they use podcasts as a form of 'trailer' for material covered more formally in scientific papers or news reports in the pages of the journals. Elsewhere, as on the website of Imperial College London, podcasts present a package of interviews on current and recent research projects at that institution; production of podcasts is also a practical training exercise for the college's students of science communication.

Individual scientists' blogs are found most readily in thematic areas where there is significant public attention and debate, for example space, climate, energy, behaviour, ecology and genetic and reproductive technologies. The blogs may be seen as efforts by such individuals to go beyond the more detached institutional stance towards public concerns in these areas, perhaps representing a strongly held personal point of view. Strong opinions are generally the motivation also for science-watchers among the general public to maintain blogs or other fora of interactive communication on science and technology. Indeed, the promise of provocative content is sometimes the lure proposed by services that host, or provide gateways to, blogs.

A journalist with Nature, writing about her own reading of blogs for possible news stories, offers a confirmation of the central argument of this chapter: 'Blogs are windows into academic coffee room chatter of the sort the media is not normally privy to' (Tomlin 2007).

Making sense of science news

The continuing proliferation and diversification of internet communication on science and technology, the strategic, even political character of some scientific institutions' internet communication, and the self-serving and partisan character of some individual scientists' internet communication all accentuate a difficulty for internet users that has already been touched on: the very widely varying types of sources of available information present significant challenges to internet users in validating and interpreting such information. Some research has shown the increasing reliance of diverse publics, notably in the USA, on the internet as a source of information on science, medicine and technology (Lacroix 2001: Miller 2001). Personal observation of students indicates that, for a clear majority of science-interested people within certain age groups, the internet is a first (and often last) resource for information on current science-related topics. Yet internet searches on more-or-less any such topic will produce many types of document from a wide range of sources: the variety includes reviewed journal papers, but also self-published research reports, statements by interest groups, news media articles, company promotions, and contributions to mailing lists or internet news groups. It takes above-average internet literacy to distinguish these different types of information and informant from each other.

The challenge to internet users is intensified by the prominent presence on the Web of science advocates in, and on the borders of, the scientific communities. In Britain, groups such as the Institute of Ideas, the Science Media Centre, Sense about Science, and the Social Issues Research Centre use their websites to promote what they see as a correct scientific approach to current issues. For some such groups, their Web presence is a response to perceived counter-science tendencies in the mass media and in society as whole. However, other internet-based services, equally accessible to seekers of scientific information, lift the curtain more on science's backstage and invite public scepticism about the motives of much contemporary science. The Union of Concerned Scientists (UCS) and the Center for Science in the Public Interest (CSPI), both based in North America, take strong positions on the social responsibilities of science; UCS focuses on environmental issues, and CSPI on food safety and nutrition. Long-established groups such as the Bulletin of Atomic Scientists and the Pugwash Conference, both of them groups of scientists and other scholars concerned with nuclear threats to global security, have broadened their audiences through the internet. In presenting their case, all these groups offer a critique of practices within science and policies for science.

In the contested area of climate science, Real Climate provides a forum for scientists, but their discussions on new evidence and its interpretation offer public insights into previously obscured science-in-process. However, in space science, where there is unusually strong participation from amateurs, and public discussions are often intense, early experience of news groups and Web discussions persuaded astronomers

to limit that view back-stage. Open disagreement in 1998 on the risk of asteroid 1997 XF11 colliding with Earth led to controversy within the space science community, not just about how such assessments are made, but also about the posting of asteroid impact predictions on the Web. The confusing controversy apparently brought no relief from the risks associated with premature judgements. In November 2000, the International Astronomical Union (IAU) carried on its website a statement that there was a one-in-500 chance that asteroid 2000 SG344 might collide with Earth on 21 September 2030. A NASA source underlined that the level of probability of a collision in this case was much higher than in any previous one. Despite the 'international expert review' of this assessment, it took just two days for 'additional information' to appear on the IAU website. This revealed that additional observations of 2000 SG344 from image archives indicated that 'the closest the object can approach the Earth in 2030 is 11 lunar distances on 23 September'. Since I gathered this material from the IAU website in 2000 (Trench 2003), the Union has become much more economical with its information. There are no longer such announcements, or any trace of previous announcements, on the IAU website. The page on near-Earth objects outlines IAU policy about the handling of reported sightings. Much more of the website's content is defined as members-only. News and published press releases relate mainly to organisational matters such as election of officers (www.iau.org). However, much of the material relating to those earlier events could be found in archives of Usenet (News) groups stretching back to the mid-1990s. Closing again the once-open curtain can never be fully effective.

In considering how interested publics deal with so much, and such diverse, scientific information on the internet, the case of biomedical science is especially sensitive. For here, the contents of professional communication can have 'end-user' value as diagnosis or remedy. Medline, the database of medical-scientific materials that is a primary research resource for medical professionals, can be accessed in somewhat reduced form free-of-charge. One early study of users of this resource showed that 30 per cent of users were not researchers, teachers or doctors, but others searching for medical information (Lacroix 2001). The National Library of Medicine established Medline-Plus to cater for these non-professional users by organising access to the database materials around topics in which users had shown repeated interest. Another US site, WebMD.com, presents 'trustworthy' information on a range of medical topics, as seen by experts in medicine, journalism and health communication; the site publishers state: 'We pride ourselves in knowing our audience's needs'. In Britain, the National Health Service publishes NHS Direct, with 'answers to your common health questions' (www.NHSDirect.org.uk). Even more obviously user-driven is a service such as IrishHealth.com, which offers users several ways to shape the content of the site.

Alongside information from such sources, which are at least partially based within the medical profession, internet users may find advice and remedies from drugs companies, advocacy and awareness groups, complementary medicine practitioners and mystics. Medical professionals fear that the easy availability of such information causes confusion and may encourage self-diagnosis. A Canadian medical information researcher worried that 'through the internet, patients not only have access to as much information as clinicians, but they are also starting to provide advice to other patients through websites that they host and

manage and email lists that they browse freely' (Jadad 1999). A British researcher notes that publishers of personal homepageson health matters have a 'clear intention ... to be a provider, as well as a consumer of health information". He suggests that the encouragement to Web-users to purchase treatment or advice represents a 'clear break with the Parsonian models of the doctor/patient relationship' (Hardey 2000).[iii]

There are several initiatives in the biomedical publishing sector, such as the Hi-Ethics Consortium, and in the government sector, such as the Science Panel on Interactive Communication and Health, to establish standards for websites that would allow users to discern professional and therefore credible, sources (McLellan 2000). This form of voluntary regulation seems most appropriate to the structures and cultures of the internet, but these initiatives have not been notably successful. They present, in any case, an obvious difficulty of monitoring or enforcement: a site conforming to agreed standards on one day. or on one document, may not do so on another.

Unavoidable uncertainty

Much of the science - notably the biological and medical science - that comes into the public domain is uncertain and contested, both from within and from outside science. These uncertainties and contests can no longer be hidden from public view. They may even become a main element of public sense-making of science news, as Dunwoody (1999) suggests:

> As increasing access to information on the Web and other outlets allows individuals to range beyond their hometown media, readers will be able to assemble meaning on a grander scale by cobbling together stories about the same topic from a variety of places. It seems almost inevitable that such trian-gulation will make uncertainty a common take-home message.

The Web's characteristics as a publishing medium, most obviously its juxtaposition of information and perspectives through search results and hyperlinking, may contribute to heightening the sense of uncertainty. But the Web also — and this is just another of its many paradoxes — provides platforms that are especially suited to the open, public negotiation of those uncertainties. By using the Web's hyperlinking capacities, and conscientiously connecting and comparing a range of perspectives and source-types, creative Web publishers can offer users a fuller picture and an understanding of the bases of uncertainty. They can do so, for example, by providing pointers to sources other than their own that may confirm or qualify the information for which they are directly responsible. They can assist the user further by adding information about information, indicating how their own information has been compiled, and offering responsible and critical assessment of competing claims and diverse contributions.

Other contributors to this volume (e.g. Irwin, Chapter 14) and to discussion of science communication more generally (e.g. Zehr 1999) have considered that uncertainty is a given, unavoidable condition of science in public. Whereas a traditional model of science communication supposed that uncertainty was progressively reduced, even eliminated, in the movement from relatively closed to relatively open spheres

of communication, a contemporary model acknowledges both that much of the science of most interest to the public is inherently uncertain, and that science-interested publics — and perhaps even the citizenry in general — are capable and willing to handle such uncertainty. That was already the view of some citizen organisations in the context of the crisis over BSE ('mad cow disease') in Britain. On the day of publication of the official report into the handling of the crisis, the director of the National Consumer Council, Anna Bradley wrote:

> The chief problem [about the UK Government's stance on BSE] was that public statements appeared to be founded on certainty — that beef was safe to eat - but they were accompanied by an acknowledgement of uncertainty ... Uncertainty and ignorance are part of the normal spectrum of scientific data.
>
> (Bradley 2000)

Such a statement implies a role for public communication of science and technology that is more challenging and more complex than the popularising, much less evangelising, roles with which we are familiar. It is a role for which the internet provides both back-stage settings and front-stage areas of performance that meet the audience's needs and expectations.

Notes

[i] Winston's law refers to the 'social constraints [that] coalesce to limit the potential of the deviceradically to disrupt pre-existing social formations'.

[ii] Habermas characterised scientific communities as bureaucratically encapsulated'; in these circumstances, general media provided a means of linking communities.

[iii] The reference is to the Canadian sociologist Talcott Parsons who, from the 1930s onwards, developed an analysis of the role of professionals that was especially influential in medical sociology (Parsons 1954).

Selected further reading

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