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Declan Fahy

American University, USA

Matthew C. Nisbet

American University, USA

Abstract

Science reporters today work within an evolving science media ecosystem that is pluralistic, participatory and social. It is a mostly online environment that has challenged the historically dominant and exceptional role of science reporters as privileged conveyers of specialist information to general audiences. We map this science media environment, drawing on interviews with journalists and writers from nationally prominent US and UK media organizations, describing the shifting roles and emerging practices of science journalists online. Compared to a decade ago, this occupational group, driven by economic imperatives and technological changes, is performing a wider plurality of roles, including those of curator, convener, public intellectual and civic educator, in addition to more traditional journalistic roles of reporter, conduit, watchdog and agenda-setter. Online science journalists have a more collaborative relationship with their audiences and sources and are generally adopting a more critical and interpretative stance towards the scientific community, industry, and policy-oriented organizations.

Keywords

digital science reporting, roles of science journalists, science journalism online

On 29 November 2010, the US National Aeronautics and Space Administration (NASA) distributed online a press release announcing that, three days later, it would be holding a news conference pegged to the electronic publication of a study – led by

Corresponding author:

Declan Fahy, Assistant Professor, School of Communication, American University, 4400 Massachusetts Avenue, NW Washington DC 20016-8017, USA

Email: fahy@american.edu

Felisa Wolfe-Simon, at the NASA Astrobiology Institute and the US Geological Survey – in the prestigious international scientific journal *Science*. The news conference promised to ‘discuss an astrobiology finding that will impact the search for evidence of extraterrestrial life’ (NASA, 2010). Reporters had already received the paper (Wolfe-Simon et al., 2010a) under embargo from the journal, a long-standing practice that enables journalists time to prepare their stories, but also aims to ensure that the journal, researchers and funders control the release of information to ensure maximum publicity (Kiernan, 2003). In this idealized system, information about new scientific findings would pass seamlessly in a linear fashion from journal to reporter to the public, only to be formally critiqued by subsequent peer-reviewed articles or in letters to *Science* and other journals.

However, the same day as the initial NASA press release, an independent blogger, Jason Kottke, speculated that the paper concerned the discovery of arsenic on Titan, one of Saturn’s moons. The next day, *The Atlanta Journal-Constitution* cited Kottke as it reported the speculation, a CBS News blog post called for some skepticism (but estimated that the announcement would be worth viewing), and MSNBC’s *Cosmic Log* blog, *Discover*’s *Bad Astronomy* blog and the independent *NASA Watch* blog all tried to reduce the speculation concerning the study’s findings. With advance access to the paper, science journalists were in a position to comment on the accuracy of the speculation but bound by the *Science* embargo policy to do so in only very limited and indirect ways. For example, *The Atlantic* senior editor Alexis Madrigal tweeted: ‘I’ve seen the Science paper. It’s not that’ (Brainard, 2010a).

The published *Science* study did not discuss life on other planets, but instead claimed ‘a more down-to-Earth, but nonetheless radical, discovery’ (*Nature*, 2010: 867). It described bacteria that had been grown using a method that replaced most of the phosphorus, an element viewed as being essential for life, with arsenic, which is generally toxic. The researchers concluded that arsenic had replaced phosphorus in the DNA of the bacteria – thereby creating a new form of life.

Several other scientists were not so sure, voicing their doubts via their personal blogs. In a post that catalyzed a surge of traffic, Rosie Redfield (2010), a microbial geneticist at the University of British Columbia, Canada, questioned sharply the *Science* paper’s methods and conclusions. Writing in the online magazine *Slate*, journalist Carl Zimmer (2010) reported that almost a dozen experts he interviewed strongly agreed that the NASA scientists ‘failed to make their case’, with sources saying there were potential flaws in the experimental research that could have affected the results.

Having initially refused to be drawn into public discussion, arguing that formal scientific communication channels such as conferences and journals were more appropriate for responding to science-based criticisms, the authors replied to the increased volume of critical comment in two announcements on Dr Wolfe-Simon’s personal website (Wolfe-Simon, 2010; Wolfe-Simon et al., 2010b). Reflecting on the controversy, *Nature* (2010) argued in an editorial that bloggers and commentators had played a central function in the overall assessment of the research findings. It concluded: ‘Many researchers’ blogs, in particular, contain better analyses of the true significance of a scientific finding or debate than is seen in much of the mainstream media.’

Understanding science journalists online

The various scientific and journalistic voices that emerged in the diverse treatments of the arsenic life story are emblematic of the wider transformations occurring within science journalism. In this study, we map this changing environment where journalists and scientists, readers and critics, professionals and amateurs, are simultaneously science content producers and audiences. We began our analysis by reviewing and integrating studies from the fields of journalism studies and science communication that described the changing field of science journalism and journalism (Deuze, 2005; Hansen, 2009; Mitchelstein and Boczkowski, 2009; Steensen, 2009; Trench, 2007, 2009) and by systematically reviewing US and UK science news content and discussion. Our goal was to identify the emerging practices for science reporters in this new digital space and the diversity of role categories that journalists are adopting. Based on this process, to inform our discussion, investigation, and analysis, we developed the following typology of journalistic roles:

- The *conduit* explains or translates scientific information in their reporting from experts to non-specialist publics;
- The *public intellectual* synthesizes a range of complex information about science and its social implications – in which the writer has a degree of specialization – presenting that information from a distinct, identifiable perspective;
- The *agenda-setter* identifies and calls attention to important areas of research, trends and issues, coverage of which is then picked up and reflected in other science news outlets;
- The *watchdog* holds scientists, scientific institutions, industry and policy-orientated organizations to scrutiny;
- The *investigative reporter* carries out in-depth journalistic investigations into scientific topics, especially where science meets public affairs;
- The *civic educator* informs non-specialist audiences about the methods, aims, limits and risks of scientific work;
- The *curator* gathers science-related news, opinion and commentary, presenting it in a structured format, with some evaluation, for audiences;
- The *convener* connects and brings together scientists and various non-specialist publics to discuss science-related issues in public, either online or physically;
- The *advocate* reports and writes driven by a specific worldview or on behalf of an issue or idea, such as sustainability or environmentalism.

To evaluate whether these categories were valid descriptions of the professional roles performed by science reporters online, we then conducted 11 open-ended, semi-structured interviews with science reporters and writers from nationally prominent, elite outlets in the USA and UK (Rubin and Rubin, 2005). While recognizing some of the method's limitations (Buckingham, 2000; Saukko, 2003), we judged this to be the best means for gaining rich data about how journalists interpreted the changes in their professional roles and routines in the digital age. We restricted our analysis to English-language elite outlets based in the USA and UK, to bound our study within distinct linguistic and journalistic contexts.

We purposefully sampled our 11 interviewees. We expected all journalists interviewed to be paradigmatic cases that would highlight general characteristics of online science reporters because of their organizational affiliation and their status, meaning that they would act as reference points for contemporary science reporting in the USA and UK (Flyvbjerg, 2004). We chose journalists who work for different media organizations, in different capacities, to ensure variability in our sample (Creswell, 1998). Four interviewees were chosen because they occupy prominent roles in elite, legacy journalistic publications: the *Guardian*, the *New York Times*, and the *Columbia Journalism Review*.¹ Two interviewees were chosen because they write for the traditional popular science magazines *Scientific American* and *Discover*.² Eli Kintisch was chosen because he works as a journalist for the scientific journal *Science*. Three were chosen because they write for innovative online science media endeavors: *ClimateCentral*, *Knight Science Journalism Tracker* and *Grist*.³ Pulitzer Prize-winning reporter Deborah Blum was chosen as she combines the prominent roles as freelance science journalist, popular science book author, professor at the University of Wisconsin, and blogger with the non-profit organization *PLoS*, which aims to make the world's scientific literature freely available.⁴

Interviewees were asked open-ended questions on how they defined their own roles, their relationship with readers and sources, how these relationships changed in the digital age, and their view on the state of contemporary science reporting. They were also asked if they regarded their work as fitting into each of the proposed categories of science reporters and, if so, how.⁵ In the rest of this article, drawing on our review and interviews, we present a synthesis, analysis and outlook on this emerging science media ecosystem and the roles played by science journalists online.

Online science content: pluralistic, participatory, social, and collaborative

For several decades, science reporters have held a privileged status as 'the principal arbiters of what scientific information enters the public domain and how it does it' (Trench, 2007: 141), a gate-keeping role that simultaneously enhanced the status of reporters, the authority of scientists, and the prestige of their institutions. Moreover, science reporting tended to conform to a transmission communication model in which information was relayed faithfully 'from privileged sources to diverse publics' (Trench, 2009: 176).

The role and function of science reporters, however, have undergone changes across decades in the 20th century. In the USA, for example, in the early decades of the 1900s, science journalism was characterized by a 'gee-whiz' mode of reporting where novel developments were translated by journalists to non-specialists (Rensberger, 2009). In the 1930s and 1940s, newspaper reporters viewed their role as persuading publics that science was the salvation of society (Lewenstein, 1992). In the 1950s, science reporters covered the details of scientific discovery, rather than science's political or social implications (Rensberger, 2009). In the 1960s, many science reporters took on a critical advocacy role, questioning the motivations and political objectives of scientists. In the 1970s, some reporters were sympathetic to the rising environmental movement. In the 1980s,

science reporting returned to a promotional style, but in the 1990s a more critical style emerged once again (Nelkin, 1995).

The current 'digital age' of science reporting is characterized by self-publishing online via blogs, social media and personal websites while also simultaneously filing traditional edited and vetted stories. At the same time, individual scientists are using blogs and other social media to communicate their work and agendas directly with various publics, creating a challenge for science reporters to not only cover the publication of new scientific knowledge in journals, but also to analyze and interpret scientific findings as they are being discussed online (Rensberger, 2009: 1056). As a partial consequence, there has been a dramatic expansion online in the availability of science-related information and a perceived diminished role for science reporters as chief disseminators of scientific content. As Eli Kintisch, who reports for *Science* magazine and writes the publication's *Science Insider* blog, reflects:

Today there are much lower barriers between my audience and information, especially information reporters used to have sort of privileged access to, that includes today digital copies of scientific papers and main sources of information such as podcasts of news conferences, transcripts of speeches, or hearings. In the past, reporters were the only ones, now there is much more broad access, including the fact that scientists themselves have blogged about the paper or event. So information goes straight to the Internet audience, versus before there was more of a privileged role of reporters as an intermediary. (Interview, 2010)

In addition, scientific publishers and societies, universities, science centers and museums, and interest groups are communicating directly with wider audiences, unmediated by journalists, often using narrative and presentation formats that were once the exclusive domain of news organizations (Trench, 2007), many even employing veteran science journalists as communication staffers. Scholars of science policy and communication, as well as critics and writers, are also producing science-related content directly online.

These trends have created 'overlapping information and communication space' (Trench, 2009: 167) in which scientists, journalists, advocates, and the people formerly known as audiences are all content contributors, each with varying knowledge, background and perspectives. This shift in the science journalism space parallels broader trends towards employing new digital formats and practices in public affairs media that enable non-journalists to be active co-producers of news content, engaging in 'pro-am' [professional-amateur] reporting on issues and events and adding their lay expertise and knowledge (Aufderheide et al., 2009; Knight Commission, 2009).

As a result, online science news and content has the potential to be highly participatory, social, and collaborative. In the United States, more than one third of internet users report that they have contributed to the creation of news generally, commented about it, or disseminated it via postings on social media sites like Facebook or Twitter (Pew, 2010a). However, even as the media system rapidly evolves, the traditional agenda-setting function of news media (McCombs, 2005) continues online, with national legacy media in the USA, such as the *New York Times* or the *Washington Post*, influencing the agenda of major public affairs-related blogs. More than 99 percent of links at blog posts reference original reporting or commentary appearing first at the traditional legacy media (Pew, 2010b).

Deep diving ‘science publics’

In this new media landscape, highly motivated users – who usually hold personal, professional, or strong political affinities for a field of science, an area of research, or a policy debate such as climate change, evolution, or stem cell research – can ‘deep dive’ into specific science-related subjects. These ‘science publics’ consume, contribute, recommend, share, and comment on news and discussion of their preferred topics across media and platforms. They expect high standards and quality for content, and they expect that content be interactive and responsive to their feedback, reposting, forwarding, or commenting (Nisbet, in press). As Curtis Brainard, who covers the science beat for the *Columbia Journalism Review*, observes:

Rather than having a readership that remains dedicated to your publication or any single publication, you’ve got readers who will find you when you’ve got something good. There’s that ability for stories from even the smallest publications, whether that be the *Columbia Journalism Review* or any other small newspaper, to really go viral and get a lot of national and even international attention. (Interview, 2010)

A diversity of deep content choices, however, also makes it very easy for these ‘science publics’ to only follow and participate at an aligned network of sites or blogs that reflect their worldviews, whether their preferred viewpoint be liberalism, conservatism, libertarianism, environmentalism, scientism, atheism, or fundamentalism. As a result, blogs such as PZ Myers’ *Pharyngula*, Joe Romm’s *Climate Progress*, or Steve McIntyre’s *Climate Audit*, which target these highly motivated yet selective publics, can attract communities of users that rival legacy media in size and depth of participation.

For legacy media journalists, navigating and synthesizing the ‘echo chamber’ nature of online science media can prove challenging. As Andrew Revkin, who writes the *Dot Earth* blog at the *New York Times*, describes his community of users:

They are sort of all over the map ideologically. The blog is very different than most in that most blogs are built to provide a comfort zone for a particular ideological camp, for liberals or conservatives or libertarians ... what I do at *Dot Earth* is try to maintain an open forum where everyone can speak. I try – and sometimes fail – to maintain constructive discourse in the comments ... And as a result it’s different. It’s a discomfort zone ... I’m not here to provide you with a soft couch and free drinks if you’re an enviro or if you are a conservative. It’s a place to challenge yourself. (Interview, 2011)

Mapping the science media ecosystem

We argue that a more suitable metaphor than the traditional transmission model for describing this digital space is that of a ‘science media ecosystem’, drawing on respected technology journalist John Naughton’s (2006) description of a new media environment online. He wrote:

The new ecosystem will be richer, more diverse and immeasurably more complex because of the number of content producers, the density of the interactions between them and their

products, the speed with which actors in this space can communicate with one another and the pace of development made possible by ubiquitous networking.

Applying this idea to scientific information content, the evolving science media ecosystem consists of legacy media in their print and online formats, including the *Guardian* and the *New York Times*; science blogging and aggregation sites, most notably SEED's Scienceblogs.com; the news and blogging communities formed by journals such as *Science*, *Nature* and *PLoS*; the news and blogging communities formed by legacy science magazines including *Discover* and *Scientific American*; science advocacy blogs and sites such as *Climate Progress* and *Climate Depot*; and reflexive and meta-discussions of science journalism at MIT's *Knight Science Journalism Tracker* and the *Colombia Journalism Review*.

Characteristic of this new science media ecosystem are innovative business models for producing science-related content which include 'quasi-journalistic ventures set up by the scientific community' such as the communities at *PLoS* and *Science*; new ventures emanating from inside journalism such as the blogs and content features at the *New York Times* and the *Guardian*; and 'developments in social networking and on the web which are both changing the way journalism is done and the way the public get their information' such as SEED's scienceblogs.com (Science and Media Expert Group, 2010: 38–39). In addition, there is a fourth model consisting of foundation funded, not-for-profit ventures such as the environment-focused sites *Grist* and *Climate Central*.

This rise in the numbers of actors, and types of models, for producing science-related content has mirrored a decline in the numbers of science writers employed by legacy media in the USA, with the workloads of the science reporters who remain increasing, with time-pressed reporters increasingly reliant on information subsidies from scientific institutions, universities and public relations agencies to find material (Brumfiel, 2009). The US National Association of Science Writers (NASW) noted that its membership in 2010 fell by approximately 200, or almost 10 percent, in a year (Krumenaker, 2010). A report on science journalism in the UK found science reporting had been largely 'spared the ravages of the US', although 'numbers employed had stagnated'. The report highlighted concerns about a lack of investigative science reporting (Science and Media Expert Group, 2010: 33).

Challenges to science journalists' authority and role identity

Occurring within wider economic, organizational, technological and professional changes in journalism generally (Deuze, 2005; Steensen, 2009), the traditional functions and practices of science reporters have shifted. Science journalists are:

Shifting from a transmission view: A two-time Pulitzer Prize-winning literary journalist, and Professor Emeritus of the University of Maryland, Jon Franklin (2006) argued that the specialism has lost its unique status and must move from traditional transmission roles into more general newsgathering cultures. Science reporter and author Keay Davidson (2006) described how his journalism became increasingly influenced by the

work of Thomas Kuhn, who proposed a non-linear account of scientific development in his *The Structure of Scientific Revolutions* (1996). Journalist Toby Murcott, a former science correspondent for the BBC World Service, said the specialism needed to ‘develop roles analogous to those of ... literary and artistic criticism’ (2009: 1054). Moreover, science journalism must now operate in a socio-cultural context where ‘traditional notions of the epistemological superiority of science, of scientific “certainty”, and of scientific authority no longer hold sway’ (Hansen, 2009: 118). The presentation of scientific certainty, a feature of the transmission view historically, has become increasingly untenable in the science media ecosystem (Trench, 2007).

Becoming critics and cartographers: Within this ecosystem with more information sources, new roles for science reporters have been predicted: they will ‘be less gatekeepers and more cartographers pointing out interesting news paths online rather than filtering and packing a closed news product’ (Santamaria, 2004, cited in Trench, 2009: 176), while roles such as ‘information specialist’ and ‘critical analyst’ are likely to be more important than ‘neutral information broker’ or the traditional reporter (Panagiotarea and Dimitrakopoulou, 2006, cited in Trench, 2009: 176).

Reporting the process of science: In the new media ecosystem, instead of journalistic authority resting heavily on being first with the news, a new kind of credibility and authority has arisen for all reporters, based on a ‘competitive logic ... one of knowing more, knowing better, knowing comprehensively, and knowing in as much depth or extent as readers would wish’. This is ‘a journalism of linking rather than pinning things down, that is situated within a model of knowledge-as-process rather than knowledge-as-product’ (Matheson, 2004: 458). Curtis Brainard said:

Some of the best science journalists are going ... upstream of scientific findings, looking at how research institutions, academic or otherwise, develop research projects, how they conceive of experiments. They’re looking at science as a process ... not just as a collection of findings. (Interview, 2010)

Adopting dialogical journalism: With different actors pursuing their agendas online, ‘notions of “authority”, “credibility” and “prestige” are in flux’ (Allan, 2006: 179). Authority online is no longer held solely by professional journalists. Authority now resides in cross-referenced, consensual understandings and the wide interactive conversation (Reese et al., 2007). Our interviewees agreed that their science reporting work involved degrees of reader collaboration. James Randerson, the *Guardian*’s environment and science news editor, noted that the paper encourages its reporters to see reader interactivity ‘as part of the journalistic process, not as a kind of add-on’. The paper’s reporting of the released climate scientist emails at the University of East Anglia offered what it called peer-review journalism, where the story’s protagonists could annotate the online coverage, to produce what Randerson (Interview, 2010) called ‘a better account, a deeper account, a broader account’ of the story. In these ways, science journalism online is fulfilling some of the predicted potential for public dialogue and participation (Allan, 2006; Nisbet and Scheufele, 2009), creating what has been called ‘dialogical journalism’ (Deuze 2003: 207). This mirrors the movement over the past two decades within science communication to dialogic models of engagement (Einsiedel, 2008).

'Co-opting' the blog movement: However, some legacy news organizations have been trying to normalize, redefine or co-opt the blogging movement, thereby 'sticking to their traditional gatekeeper function even with a format that is explicitly about participatory communication' (Singer, 2005, cited in Mitchelstein and Boczkowski, 2009: 574). Pulitzer Prize-winning journalist Deborah Blum elaborates:

We are starting to finally see blogging networks or collectives take place. It's the gatekeeper thing ... are we starting to say, well, let's have these networks and that adds an extra layer of credibility to the blog. Don't read every blog, which is almost like old fashioned journalism, right? – don't read every editorial, read the editorial in the *New York Times* – don't trust every blog, trust these blogs. (Interview, 2010)

Alok Jha (Interview, 2010), science correspondent for the *Guardian*, discussing the paper's expansion of its science blogging community in 2010, said that the collaboration was mutually beneficial as the site received deeper coverage and bloggers communicated with an available and attentive audience.

Science journalist roles: identifying shifting roles

Changing journalist roles within the science media ecosystem reflect economic trends in the international news industry in which 'workers compete for (projectized, one-off, per-story) jobs rather than employers compete for (the best, brightest, most talented) employees' (Deuze, 2009: 316). Since freelancing relies on maintaining multiple streams of income-related activity, the trend has driven an increase in the diversity of roles that a science journalist might pursue. Examples of journalists performing the roles typologized at the opening of this article have always existed, but the distribution of journalists across categories has grown more diverse in recent years. This trend is pronounced in US science journalism, with Blum noting that the industry-wide move to freelancing has:

... driven our changing perception of what a science journalist is. A science journalist wears a lot of hats, the way I do ... I write books, I do magazine articles, I teach – [this] is much more the twenty-first century version of a journalist. (Interview, 2010)

The reporters interviewed described how their work exhibited the characteristics of the proposed role categories of online science journalists, roles that we found to be not equivalent and frequently overlapping.

Conduits and explainers: Despite the imperatives for role diversity driven by the increased number of freelancers and the new online content features such as blogs featured at legacy media, a consistent theme among the journalists we interviewed was that the traditional role as reporting new scientific developments remained a cornerstone for their work. Jha noted that the main goal was reporting 'what's happening and what's interesting. That's the primary thing' and he noted that other roles and functions flow from this primary reporting role. Charles Petit (Interview, 2010), a veteran science reporter and lead writer for MIT's *Knight Science Journalism Tracker*, said science reporters 'explain current events by asking scholars about them, and these tend to be

scientists'. Jha (Interview, 2010) was careful to distinguish this reporting function from roles as 'conduits' and 'explainers'. Petit said the reporting role was previously 'much more dominant among science writers' and 'it remains important'. Blum (Interview, 2010) and Ed Yong, who writes the award-winning *Not Exactly Rocket Science* blog for *Discover* magazine, were among reporters who said a core feature of their writing was explaining science understandably to non-specialists. Yong (Interview, 2010) said:

I think that area of science reporting often gets forgotten about in the mainstream. I'm not sure it's as valued as strongly as – I don't know – uncovering acts of fraud or misconduct or finding juicy human stories. I think the very simple act of making complex things simple is tremendously valuable. It's essential for science journalism.

Curators of information: Interviewees generally agreed that sifting through and evaluating the vast amount of science-related content has become an increasingly prominent function for science reporters. The *Guardian*, for example, created Story Trackers, which trace the coverage and commentary on major science stories as they develop, with readers actively pointing out interesting coverage. Randerson (Interview, 2010) said that, with so much science content available, curation is 'about what it means to be a journalist in the digital age'. He said:

We made a very conscious decision to add value to stories by doing this kind of curation role, and basically admitting that we are not the fount of all knowledge, that we do have the ability to present information in a useful way and to hopefully decide which information is useful and which isn't, and to try and bring in the information that's good and present it in a way that's meaningful, and to use our readers, our readership, and the people who are part of our community to help us in that task.

His colleague Jha (Interview, 2010) said curation of stories where there are multiple angles and perspectives on the issue also allows for a more realistic portrayal of scientific work because 'scientific papers when they are published are not the be all and end all. They are the start of a massive conversation.' Curation is also an important function for producers of meta-discussions of science journalism carried out by, for example, The Observatory column at the *Columbia Journalism Review*. Its editor, Curtis Brainard, noted that curation was more than aggregation of content and adding value to stories is essential. He said:

It means informed or value-added aggregation. If you go to a museum, the curators don't just put up a painting; they also put up a little sign next to it, explaining something about that work. That's more what we do, that informed aggregation ... We're collecting headlines, but at the same time, we're telling you why we're recommending this story, or why we're recommending you don't read this other story. (Interview, 2010)

David Roberts (Interview, 2010), a staff blogger with *Grist*, added that the volume of information has meant that 'just about everyone online is being forced to play that role sometimes these days', but for him, the curatorial role has moved to Twitter, which is 'just a much handier tool for the job'.

Civic educators: While science journalists have traditionally been resistant to viewing their work as education (Radford, 2006), some interviewees noted that the limitless availability of space online allowed reporters to fulfill more an educational role. Brainard (Interview, 2010) argued:

Before digital media, the news was the news, and yesterday was ancient history. There was no efficient way to archive information for the public at your traditional news outlet. But now, the web has changed all that and so journalists need to be not only presenting the news, but they need to make pertinent background information readily accessible ... the web allows us to do that. News outlets should almost develop these encyclopedias at their back end. The *New York Times* has done a great job on this.

Contextualized science reporting has an education function, according to Yong (Interview, 2010), not only promoting scientific achievements, but also showing 'where scientists disagree, areas where controversies are going on, because that's part of science, that's an inescapable part of the scientific process ... it shows people scientists are human and that science is a human process'.

Several journalists interviewed, however, were resistant or ambiguous about this role. Jha (Interview, 2010) noted that it's 'a role that if it happens, then great ... but it's not the primary intention'. Mike Lemonick, formerly of *Time* magazine, now with *Climate Central*, and who teaches at Princeton University, said that most journalists have a strong resistance to the educator role:

Educators identify areas where knowledge is necessary, and provide it. An educator provides a discrete body of knowledge; they try and tell you everything about a certain subject, within limits of time. [Journalists] put educational content in a story in order to make news understandable. Another thing we do not do is assess what was learned. (Interview, 2010)

Public intellectuals: Reporters in this role are similar to traditional newspaper commentators or columnists, moving frequently between specialized topics that they present from their distinctive worldview (Fahy, 2009). Several interviewees were resistant to being classified in this role, but John Horgan, who writes the *Cross-check* blog for *Scientific American*, contributes to science magazines and writes popular science books, is the interviewee who illustrates this role most clearly. While working as a staff reporter for *Scientific American* in the 1990s, he said he 'became dissatisfied' with the constraints of traditional reporting and he wanted to undertake more opinion-based, interpretative reporting. He classified himself as a 'critical debunker' and said he looks for 'exaggerated or erroneous scientific claims' that he tries to question and debunk. Horgan said:

I convinced myself that that was actually a good thing to do because science had become such an authority that there was a need for a scientific critic ... I just enjoy that form of journalism myself. It's a paradox: it's using subjectivity to ultimately get a more clear, objective picture of things. (Interview, 2010)

Agenda-setters: Randerson (Interview, 2010) said a distinct role for science reporters remained 'being able to project the story ... The readership and the influence of the

Guardian are very important in terms of making a story acquire legs and really start moving and change what governments think.’ A form of agenda-setting is happening also through social media, with Revkin (Interview, 2011), for example, sending out his blog posts through Twitter ‘sort of to test the idea and get it propagating’. Brainard (Interview, 2010) noted: ‘One thing that hasn’t been lost in the media is that desire to be first ... We love it when we can get out with an analysis before anybody else and become the foundation on which all the following coverage is built.’

Watchdogs: Interviewees agreed they generally fulfilled the watchdog role, over scientific institutions and the scientific community, but also over individuals or groups making false scientific claims, and over social actors intervening in science policy discussions. A quote from Jha (Interview, 2010) is representative: ‘We are playing watchdog, but on all sides, really.’

Conveners: Science reporters connect scientists with various publics to discuss science. Revkin (Interview, 2011) said this was a major part of his current work, either online or in person. He said:

A big subset of posts that I do are along those lines. When I go places to speak, quite often I’ll be in the role of moderator or kind of convener ... where I am on stage with four or five scientists or technologies or engineers or academics and challenging them in the same way as I do on the blog.

Conclusion

We have approached this article as laying the groundwork for additional research examining the rapidly evolving science media ecosystem and, as a result, we recognize the limitations to our analysis. We focused on elite media in the USA and UK and future research might explore the extent to which a similar ecosystem exists in other political, linguistic and journalistic cultures. We chose to base this first part of our longer term study on elite media, rather than local or community media, which may not have the resources or organizational capacity for its reporters to undertake the variety of roles outlined here.

The new science media ecosystem in the USA and UK that we have mapped in this article – a mostly online environment that is deeply pluralistic, participatory and social – has presented challenges to the traditional professional role and working practices of the science reporter. In this environment, journalists have moved from their dominant historical role as privileged conveyors of scientific findings to an increasing plurality of roles that involve diverse, pluralistic and interactive ways of telling science news.

The increasing plurality of roles has been driven also by the shifting economic and career conditions for science journalists, who are, with increasing number in the United States, working as freelancers. The increase in role diversity is also a function of news organizations requiring their staff journalists to not only master various multimedia storytelling and newsgathering formats, but also report, write, create, and communicate across multiple mediums and in different formats. The roles that are becoming increasingly prevalent are *curator*, particularly, *convener*, *public intellectual* and *civic educator*, roles that are underwritten by the essential skills of criticism, synthesis and analysis.

There remains, however, as described by our interviewees, a strong continuation of the traditional journalistic role conceptions of *conduit* and *agenda-setter*. The traditional *reporter* role emerged in interviews as being more fundamental to online science journalists than we had anticipated at the outset of our research.

Journalists also strongly identified with the *watchdog* role, stressing that this meant they covered critically the scientific community itself, new scientific findings, challenges to scientific knowledge, science policy claims and, indeed, science journalism itself. Yet, as several interviewees stressed, critical, interpretative, analytical reporting cut across several roles, suggesting to us that the structural, organizational and professional changes in the digital age have enabled science reporters to more generally fulfill the historically much hoped for roles of science critics and civic interpreters.

Despite the rise in advocacy journalism (Barlow, 2007), none of the interviewees self-identified in the *advocate* role. In addition, apart from some examples from established legacy media, the interviewed journalists did not self-identify strongly as investigative reporters, with reporters noting that legacy media had the resources and expertise to conduct investigative reporting, but, in the USA at least, investigative work is now being carried out by, or in partnership with, non-profits, universities or philanthropically supported organizations, such as ProPublica or American University's Investigative Reporting Workshop. The trend toward non-profit models that have flowered among a collaborative network of investigative reporters has been comparatively slow to develop in similar fashion among science journalists.

Still, there are existing non-profit models in science journalism that future research should examine, including *Climate Central*, *Yale Environment 360*, and the *Yale Forum on Climate Change and the Media*. Yet these models stand as just six among what investigative reporter Charles Lewis (2010) has identified as more than 60 non-profit public affairs journalism initiatives at the national and local level in the USA. Given this growing population of ventures, future research should attempt to systematically account for the features and principles that can usefully inform the growth of non-profit science journalism.

Appendix: List of interviewees – Interview on shifting roles of science journalists online

- Blum, Deborah: Telephone interview by Declan Fahy, 16 December 2010.
- Brainard, Curtis: Telephone interview by Declan Fahy, 14 December 2010.
- Horgan, John: Telephone interview by Declan Fahy, 10 December 2010.
- Jha, Alok: Telephone interview by Declan Fahy, 21 December 2010.
- Kintisch, Eli: Telephone interview by Matthew C. Nisbet, 29 December 2010.
- Lemonick, Mike: Telephone interview by Matthew C. Nisbet, 9 December 2010.
- Petit, Charles: Telephone interview by Declan Fahy, 12 December 2010.
- Randerson, James: Telephone interview by Declan Fahy, 22 December 2010.
- Revkin, Andrew C.: Telephone interview by Declan Fahy, 4 January 2011.
- Roberts, David: Telephone interview by Matthew C. Nisbet, 9 December 2010.
- Yong, Ed, 2010: Telephone interview by Declan Fahy, 23 December 2010.

Notes

- 1 Andrew C. Revkin, former environment correspondent for the *New York Times*, writes the *Dot Earth* blog for the newspaper. James Randerson is environment and science news editor with the *Guardian*, and Alok Jha is science correspondent at the same paper. Curtis Brainard is editor of The Observatory column at *Columbia Journalism Review*.
- 2 John Horgan is the author of several popular science books, including *The End of Science* (1996), and writes the *Cross-check* blog for *Scientific American*. Ed Yong writes the *Not Exactly Rocket Science* blog at *Discover*.
- 3 Mike Lemonick is senior writer at *ClimateCentral*, Charles Petit is lead writer at MIT's *Knight Science Journalism Tracker* and David Roberts is staff writer at *Grist*.
- 4 Other interviewees sampled occupy similarly overlapping professional roles. Revkin is Senior Fellow for Environmental Understanding, Pace University, Pace Academy for Applied Environmental Studies. Horgan is Director of the Center for Science Writings at the Stevens Institute of Technology, Hoboken, New Jersey. Lemonick is a contributing writer with *Time* magazine and Lecturer, Princeton University. These interviewees were purposefully sampled as we expected them to offer reflections on contemporary science reporting from perspectives grounded in a variety of professional roles.
- 5 The research was approved by American University's Institutional Review Board and interviewees gave their consent for their views and opinions to be cited directly.

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Biographical notes

Declan Fahy, PhD, is Assistant Professor in Health, Science and Environmental Journalism in the School of Communication at American University, Washington, DC. His research examines emerging models of science journalism and representations of scientists as celebrities and public intellectuals.

Matthew C. Nisbet, PhD, is Associate Professor in the School of Communication at American University, Washington, DC and Director of the Climate Shift Project. His research in the area of science communication examines how mental models, social identity, and media use shape the perceptions and actions of experts, decision-makers, journalists, and different segments of the public.