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CHAPTER 13

Afterword: Social Changes in Science Communication: Rattling the Information Chain

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Scientific writing has always been changing, moved by multiple forces—some of them under the inventive control of writers and editors creating articles and journals; some evolving from the communal interactions of emerging and changing scientific communities and their ways of pursuing investigations; some responsive to larger organizational, political, and economic arrangements within which science operates; and some exploiting the opportunities afforded by changing communicative technologies. The forms and appearances of texts are the realizations of communicative actions within these larger sets of forces. What we may think of as the standard forms of scientific communication are only semistable sets of expectations that emerged gradually since the invention of journals in the 17th century. While some features arose early in this history, some only took on robust form in the 20th century, as science came to reside at the intersection of university departments and professional societies (with their structures of rewards and advancements), government and business interests and funding (based on their perceived needs for scientific and technological knowledge), knowledge-based professions that pervade contemporary society (with their reliance on systems of authority and credentials), expanding educated populations who look toward science for knowledge, and evolving technologies and systems for the production and distribution of texts (including cheap printing, commercial publishing companies, university and professional libraries, national mail systems, and international agreements).

Reinforcing dynamics have served to carry forward the 20th century expectations even as technology has afforded new opportunities for the production, format, and distribution of communications as well as opportunities for institutional, financial, and social change. Disciplines had already coalesced long before the Internet around regional and international societies, with local instantiations in university departments. Standards for work became defined in the disciplinary societies relying for legitimacy on university affiliations and credentialing. Leading journals were established and built long reputations. Societies and corporations became dependent on the profits from the production of these journals. Health care, military, economies, and other social sectors became dependent on the production of this knowledge and looked to universities and academic disciplines. In recent decades, university status has increasingly come to depend on the production of research, measured by the production of refereed and cited articles. Faculty rewards have coordinately become increasingly dependent on productivity, measured by publication in recognized academic journals supported by practices of communal judgment, especially as universities and graduate programs expanded, creating more competition among themselves with an expanded job market and an even more rapidly increasing pool of job candidates. Competition has also increased for funding, status, recognition, and students. With increasing intensity, countries of all regions have entered the world of research and sought status.

At the communicative center of this competition were publications presenting the kinds of argument that would gain disciplinary acceptance as contributing to the advance of knowledge valued by the discipline. Such contributions would meet disciplinary standards, would be useful to relevant stakeholders, would raise the status of individuals, and would produce reliable knowledge. Contributions would also articulate with other contributions in the field, which might be sharply distinguished from work in even closely neighboring fields. If the contribution were to be considered of value to multiple fields, it had to speak to needs and standards of each of the disciplines and professions. The form and evaluation processes were intertwined, in that the expected forms of reporting results and arguing for claims embodied criteria of the field that needed to be addressed for credibility. Texts had to meet these criteria and make credible arguments not only to pass refereeing and editorial judgments but to become cited and used, establishing the basis for future work, creating track records for reputations of researchers and research programs, and establishing the basis for fundability of future research.

The focusing of the research question; the articulation with prior knowledge and other current results; the methods for production, selection, and display of evidence; the presentation and analysis of the evidentiary findings; and the valuation of the research for advancing the thinking of the field became important for most fields, through differences in the specifics of each field, led to major differences in the genre details in the publications of each. Additional genres

arose to pursue specific elements of these functions in a more focused way (such as reviews of the literature, methodological articles, or theoretical pieces). Also, the coherence of reasoning of these parts was held together in a larger textual structure that either implied or made explicit the overall logic of the argument. On the surface, these elements typically add up to the IMRAD structure (that is, Introduction/review of literature; Methods; Results; Analysis; Discussion), but there are many variations across the fields. Further, as fields evolved, so did the methods, kinds of available evidence viewed as relevant, the accumulated literatures viewed as currently relevant, the theories that bound contributions together, the forms of analysis considered revealing, the stakeholders whose needs must be met (such as the changing roles and relationships of government regulatory and provider agencies, health providers, research funders, and healthcare business that had interest in medical and pharmacological research), and many other elements that might influence the contents and shape of articles.

Yet no matter what the particulars in each field at each moment of time with respect to each research inquiry, the article needed to present the various relevant elements in a coherent integrated structure that in its totality argued for findings or a claim. Disciplinary evaluation of the credibility of the contribution depended both on the adequate performance of each of the elements and the total argument facilitated in the total article structure. This would be true even though most readers may not read the article fully or in chronological order (Bazerman, 1985) because all elements would be there for reviewers evaluating the suitability for publication and for any readers who had need or motive to look more deeply into the claims.

During the last decades of the 20th century, digitization entered into this strongly reinforced though potentially mutable arrangement, changing the means and economics of the production and distribution of texts and data, the convenience of multimedia components, and the ease and pace of collaboration and other communicative interactions. Digitization also potentially could affect all the components of the surrounding social, organizational, and economic systems that surrounded, energized, and shaped the system of scientific knowledge production. This current volume, *Science and the Internet: Communicating Knowledge in a Digital Age*, takes up the question of what has changed, in what way, and to what degree, particularly with respect to the Internet.

So what is changing, at what level, with what consequences for future changes? What remains stable, what is facilitated, what is made more intense, what is disrupted, what is a more attractive alternative path? When do small changes coalesce in major reinvention? The chapters in this book provide a series of cases that look at texts, websites, and other textual realizations to see what is visible in the form of the text; but in these changes we see indications of less visible underlying social changes that in the long run may lead to bigger changes than anything now noticeable. That ability to expose small signs of bigger things to

come is one of the advantages of case studies. Each of the chapters has taken up interesting cases—that is, cases where novel or previously unexamined or previously unappreciated changes seem to be occurring. This is not surprising because in case study research, the novelty of one's findings often depends on the novelty of one's cases—the researcher wants to be able to tell an interesting and engaging story, typically by making visible something the reader was previously unaware of. Further, each case can look into detail as to the specific elements emerging in the communications and the social and scientific histories that lie behind the communications examined in detail. Each case serves as something of a demonstration proof—something can happen because it has happened. The forces that have shaped situations and the motives that have driven those who are responsible for producing texts (this includes editors, publishers, societies, and authors) have coalesced at least once, and the choices made by the actors are imaginable and implementable because they have been made and done. Indeed, in this volume, every case is one of novel happenings. No study focuses on what remains the same, stabilizing tendencies, or cases of "nothing going on here." Even when the reported novelties are facilitations or intensifications of long-standing practices, the studies emphasize what is new rather than what is continuing in somewhat altered shape or by altered means.

While case studies are good at making visible interesting occurrences, they are less good at evaluating overall trends within a large and varied population, particularly at a time of hypothesized change where there are many experiments and many different choices being made. Only when the new situation has achieved new semistability can we determine which innovations have lasted robustly, responsive to which purposes, concerns, and interests. Even then there will not be uniformity, and minority experiments are likely to endure, depending on the rigidity and comprehensiveness of social evaluation, selection processes, and authority structures that come to rule within any particular epistemic social grouping. For examining broader trends, larger samples are needed, to some extent handled through statistical means. One chapter in this collection (Harmon) does carry out a broader survey, but before I discuss that chapter, it is useful to look more closely at a book cited by Harmon and three of the other authors in this collection: Owen's *The Scientific Article in the Age of Digitization* (2007). Although Owen's data ended in 2004 and may not have caught some more recent trends, he did examine an extensive, systematically designed sample of all digital journals. Owen found evidence of both change and stability, but found the weight dominantly on the side of stability. Reasonably enough, a set of cases making visible changes would be set in contrast to Owen's findings, as the authors in this volume who cite Owen tend to do. Yet what Owen finds is not so different from what these authors find. Seeing these two volumes in coordination rather than at loggerheads might help sort out the real forces of change that they both point toward.

Owen (2007) first reviews theoretical models that would predict change, including an entire chapter about how research moves from the laboratory into the communicative sphere. In this chapter on what he and others have called the information chain (following on an earlier article, Owen, 2002), he argues that digital production and distribution has great potential to reconfigure the scientific communication system. I quote at length because this is perhaps the most transformative element in Owen's analysis and because it bears on some of the more striking developments noted in the chapters in this volume:

> The traditional communication system has evolved towards a high level of closure with respect to functionality, actors and role divisions. However, it seems that digitization is opening up the system considerably. Publishers and libraries are taking over each other's functions, some functions are becoming embedded in the digitized network system, and others are being taken over to a certain extent by authors and readers or their parent institutions (e.g., in the form of "self-publishing"). In addition, various new functions have emerged (such as pre-publishing and long-term archiving) that require some form of control and actor-involvement. Ideas have been developed for a more radical effect of digitization, leading to a transformation towards an entirely systems-mediated form of communication without any involvement by institutional actors. We have seen, however, that many important functions of the information chain, and especially the certification function, do require such involvement.
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> In fact, rather than becoming more simple . . . , scientific communication is becoming more complex. The flow of scientific information from author to reader is no longer a single, well-defined process, passing distinct stages governed by actors with strictly assigned roles. Digitization has resulted in an increase in genres, actors and communication modes, with multiple trajectories through which scientific information can flow, and multiple access points for users to acquire that information, depending on the stage in the life cycle of the publication. (Owen, 2007, p. 90)

Owen then presents the results of the study of a sample of 186 established and continuing peer reviewed, digital-only journals distributed across the sciences, social sciences, law and humanities. These journals were examined for 11 dimensions of article properties and 4 dimensions of editorial policies to see how much they differed from traditional print journals and took up special affordances of digital production and distribution. On some dimensions, he found little uptake of digital affordances. For example, in only a few journals were authors allowed to submit fully formatted articles; authors were generally required to submit flat formats, following fixed style guidelines, leaving the formatting and typography to editorial processes. In almost all cases, revision ended at a date of final publication. Similarly, there was little customization of articles for readers' needs (beyond allowing readers to create personal collections files of articles). On the other hand, some digital features were taken up in small but substantial numbers,

often depending on discipline, such as presentation of data resources and use of multimedia. Some journals provided opportunities for reader comments, and 8% used a degree of open peer review, though often within hybrid models that maintained elements of traditional peer review. Finally, some digital opportunities gained wide acceptance, such as hyperlinks and navigational tools within articles and journals. Also, digital systems were widely used to facilitate traditional peer reviewing, and open access ideology was changing copyright policies, with half the journals asking only for rights of first publication, leaving ownership with the authors.

These findings lead Owen to conclude that uptake of digital affordances is selective based on choices that differ across situations and across disciplines. However, the features of digitality incorporated to this point have not disrupted the integrated structure of the total article, which had historically emerged and which seems to have migrated to the Internet in a process of "encapsulization." In Owen's words,

> So it is not the case that the digital medium has certain properties that will inevitably be conferred on any genre that uses it. Rather we shall (and do) see a wide range of different applications where each genre or practice of communication is made to adopt, at any point in time, a specific set of digital properties or "digitality." Some practices of communication may indeed be transformed (though not by new media as such, but by choices made by social actors that "construct" what is perceived as new media), others may stay very close to their traditional modes of representation. This view is supported by the existence of a certain amount of communicative heterogeneity between different scientific domains. There is no single "digital medium" in science but a whole range of different manifestations of digital properties. None of these has, as we have seen, transformed formal scientific communication insofar as it is based on the peer-reviewed research article. In evolutionary terms, scientific communication has adapted itself by process of encapsulation: through digitization of the journal as a container, the scientific article is able to remain relatively stable even within a digital environment. (Owen, 2007, p. 216)

Given the narrative I have presented of the robust forces aligning to shape the contemporary article and the role of the coherent argument for making claims based on systematically produced evidence and positioned as contributions within disciplinary literatures following disciplinary standards, the encapsulization Owen (2007) reports is not surprising, particularly in light of the importance of evaluation of the argument prior to publication and for use after publication. Individual and institutional rewards depend on these evaluations, which lead to publication in esteemed venues and citation following publication. Owen notes the importance of the certification function, which still seems to require institutional involvement. Encapsulization rests on social forces that hold

it together, and in the long run, the greatest changes may come from the different ways people come together over shared and competitive information as individuals and as located within institutions and social groups—changes in the information chain. It is with respect to these changes that I find the analyses of the cases in this volume most interesting, and it is these changes that are starting to motivate changes in textual form and fray the solidity of encapsulization—though the ultimate result in the form of scientific communication is too early to tell.

As to the actual developments in the form of scientific articles, there is only one survey in this volume that attempts to directly answer Owen's (2007) survey. In this volume, Harmon choses a more up-to-date sample of ten articles from each of 15 journals from 2010 and 2011. He examines 10 long-standing elite journals that appear both in print and online and 5 recent journals that are digital open access. Unlike Owen's sample, Harmon's smaller sample comes entirely from the sciences. The dimensions he examines include authorship, abstracts, inter- and intratextuality, visualization, organizational structure and supplemental information, readers' comments, and journal contents pages. The samples, analytical categories, and ways of reporting results differ from Owen, making exact comparisons difficult; nonetheless, for the most part, Harmon's findings follow the trends noticed by Owen, only a few years further down the process. Owen had noticed some use of multimedia; Harmon notices an increasing use of visualization and greater use of color than in print and the use of links to allow readers to see expanded images, though videos are still a rarity. Owen had also noted some use of data supplements, as does Harmon. Owen notices a minority of journals offering opportunities for reader comments as does Harmon, but Harmon also noted some journals now provide download statistics as another measure of reader response. Owen noticed widespread use of internal and external links to heighten intra- and intertextual linkages, as does Harmon. Harmon, like Owen, notices large and increasing use of navigation devices within the article and for the journal. Harmon finds, on the other hand, no major change in article structure and widespread use of the PDF format, both of which substantiate Owen's view of the article as encapsulated as a fixed form.

Harmon additionally finds changes in dimensions not considered by Owen (2007): first, the use of simplified summaries and other accessibility devices to make the article's findings available for those who do not wish to or are not prepared to delve more deeply into the full abstract or the full text. Secondly, Harmon notices an accelerated trend in multiple authorship from diverse regions. While these on the surface appear to be minor changes in the actual form and structure of articles, they may be indicative of deeper changes going on in the social organization of scientific communication. But on the surface, Harmon only finds incremental differences from what Owen found a few years earlier, and neither found radical disruption of the encapsulated paper, only enhancements or intensification of earlier trends supported by the conveniences and affordances

of digitization and the Internet. The main difference between the two sets of results is that Owen puts the weight of emphasis on the more stabilized parts, and Harmon puts more weight of emphasis on the changing parts.

While the formal changes seem gradual, facilitative to prior dynamics, and nondisruptive, the cases in the volume reveal in greater detail what these changes are, what led to them, how they operate in changing interactions, and what their implications and consequences may be for communications internal and external to science. Even more, as several chapters note, digital distribution and participation may be calling the internal/external distinction into question in both production and use of scientific communications. I would also like to consider the clues that a number of both the internal and external communication cases may say about the changing social relations and distribution of work of science, which may in the longer run be more disruptive of the encapsulization of the scientific article than anything that now has yet crystallized in a changed form of scientific article.

Four of the five cases examining internal communications of science involve postpublication commentary on published science and illustrate the communicative efficiency of the Internet in intensifying long-standing dynamics of evaluation and accountability after the fact of publication. Publication does not in itself bring long-term acceptance of claims or incorporation into the body of accepted knowledge. That has depended on how reliable and useful others have later found that work and whether they take it up in their own writings to carry the contributions forward into a lived and intertextually strengthened body of knowledge. Disputing counterpublications, failures of replications, contrary findings, questions about methods, ethics accusations and investigations, and retractions go back at least to the early days of the *Philosophic Transactions*. Such contesting communication have influenced the long-term evaluation, uptake, and codification prospects of claims that gain the attention of scientific peers, although the greatest mechanism of long-term evaluation was and remains inattention and lack of citation. Claims not considered important, interesting, or useful enough to be worth a lot of discussion and gather significant uptake, vanish, even though no one may contest them. In the past, when discussion has been excited, however, long-term processes of discussion and evaluation have been somewhat slow and sometimes porous. The four cases of scientific Internet commentary culture here indicate the Internet is providing potentials for speeding up and strengthening postpublication evaluation and codification. Buehl's introductory case of blog response to a purported breakthrough claim published in *Science,* Gross' study of the blogs *Retraction Watch* and *Abnormal Science*, Sidler's discussion of a liveblogging event, and Casper's analysis of various forms of refereed and nonrefereed online comments all show how critical questioning, accountability, and postpublication evaluation of articles have found new and highly effective sites for what had been long-standing elements of scientific communication.

The *Retraction Watch* and *Abnormal Science* blogs that Gross documents have intensified inspection of published articles and made it far more likely that serious accusations of fraud, plagiarism, other violations, and retractions do not get lost in the interstices of a loosely articulated communication system. The blogs rely not only on the visible and widely available publication and archiving space they offer, but on the rapidity of response, and the search tools of the Internet that allow more convenient and comprehensive tracking of the fate of retractions and disputations. These blogs tighten the accountability noose. They do not seem to change the nature of the articles themselves, however, except by helping police that publications live up to long-standing expectations. At what point and in what way this more intense house-cleaning may have transformative consequences remains to be seen.

Sidler and Buehl's cases, on their faces, similarly seem to be only speeding up and intensifying postpublication evaluation processes. Each reports a controversy that erupted in unrefereed blogs within a day or two after the appearance of a highly controversial claim within a prestigious refereed journal. While for centuries postpublication controversies could circulate informally among limited groups in seminars, on the floor of conferences, in letters, and in other *ad hoc* sites before they appeared in the refereed scientific literature, blogs have allowed widespread publication and professional debate outside the reviewed publication system. In Sidler's example, the appearance of extraordinary claims in the *Journal of the American Chemical Society* that seemed to contradict well-established findings led to immediate attempts at replication, including one that was liveblogged with data, images, and comment posted in real time—all self-published by the bloggers and commentators outside the review process. The original article was rapidly discredited by the blog discussion, and there was consternation as to how it passed prepublication review. For some, this case suggested that blind prepublication review might better be replaced with open peer review. Buehl's case concerned the blog questioning of an article appearing in the online version of *Science.* The article claimed discovery of life forms that replaced phosphorous with arsenic; within two days, blog critiques appeared and followed with such intensity that by the time the print version appeared 6 months later, it was accompanied by eight technical comments and an analysis of the controversy. It should be noted, however, that the publication of the peer reviewed technical comments had the effect of bringing the discussion back within the peer review system.

Rapid and unrefereed commentary is now also being invited on the same page as refereed articles appear in online journals. Casper compares such notes and comments in the online-only *PLoS ONE* with older forms of refereed and edited letters to the editor in *Science*, which appear in both print and online versions. The unrefereed notes and comments appear in proximity to the article in both time and textual space; they tend to be shorter, more informal, and more dialogic; they raise more questions about the production of work in contrast

to the more polite and formal e-letters and letters to the editor, which are more concerned with the status of the knowledge claims of the article. As a result of the dialogic interchange in the notes and comments, authors sometimes amend their articles in subsequent notes also published in proximity to the article. These postpublication commentaries therefore lead to revision of the published article in ways similar to prepublication review. Casper also raises the possibility that authors may write articles differently, anticipating the kind of intense interaction that may occur in the new commentary environments, even as writers had previously come to write articles with an awareness of the review processes manuscripts would undergo. While it is too early to have clear evidence of such changes in manuscript, this is precisely the process I found in early print journals as certain kinds of issues became salient in the interactional space of journals that got lost in the more distant interactions of books. To forestall criticisms, authors preemptively wrote their articles to address concerns over conditions of observations, methods of producing results, and precise details of results (Bazerman, 1988). This process of finding more successful ways of creating arguments that would be persuasive in the new more intense forum was one of the key drivers of the emergence of what has now become standards of scientific publication, reinforced by later-emerging reviewing and editorial practices.

The cases examined by Buehl, Sidler, Casper, and, to some extent, Gross all point to a loosening of editorial control over the evaluative process and publication of critiques, but primarily postpublication, though we see some of the pre- and postpublication lines blurring, with corrections and revisions on the basis of postpublication commentary being made available with the original article. Whether and how such processes might influence prepublication processes and published articles is still unclear, but the effect on published critiques already is becoming evident. The kind of informality, methodological critique, and questioning of evidence Casper found in the notes and comments that appear following articles also seem to pervade the blogs examined by Buehl, Sidler, and Gross. Because all these comments are not preauthenticated by review processes, the weight of argument must fall even more on precise and focused reasoning in direct engagement with the articles being commented on. This intense discussion, sorting out the reliability and value of claims within a rapid-fire public space of contention, does seem to be a real change in the postreview evaluation process. In the print world, although sometimes controversies erupted in print over claims, the weight of postpublication evaluation depended on citation and reuse, and eventual codification in review essays, handbooks, and textbooks. While prepublication open peer review has only worked in a few fields (with one of the major difficulties being the lack of voluntary labor needed to vet the large number of not-yet-authenticated submissions), controversial claims upsetting expectations within published articles seem to draw the attention of critical audiences and foster heated discussion in more direct communicative spaces without publisher intermediaries.

A potentially even more radical disruption of the encapsulated article may be the open data archives described by Wickman. In the past, data notebooks or archives were the responsibility of individual researchers or research teams and were, in a sense, private resources for their own research—resources to be drawn on selectively for evidence in publications authored by the individual or research team. These data archives could have been shared or made public in particular situations and by intentional actions, such as if research had been questioned and other researchers wanted to confirm findings. Data archives could also have been made public to support further research, but in such cases, the data would have been organized and prepared as a special section of the publication to make them useable and interpretable by future users. Responsibility and accountability for the archives and the quality of the data would have remained with the initial research group that published the archives. The *OpenWetWare* site that Wickman examines adopts a Web 2.0 ideology and a wiki structure for the core data and protocol pages, thereby distributing responsibility for the regulation, design, contribution, and revision of datasets offered at the site. It also includes blog spaces for commentary, software tools for creating notebooks, and pages for groups and courses to post and share materials about their activities. The site also includes specific procedural information for syntheses of particular substances for those entering each problem area, to regularize procedures among researchers, to standardize produced samples for investigation, and to assure a common understanding of data. So the site goes far beyond a sharing of data to a shared development of common ways of work and methods of interpreting findings. The standardization of notebook formats also serves to standardize the reporting of data. This degree of sharing and co-production of procedures and data prior to publication may redefine what will count as the contribution of an individual author or research group and what decisions the author(s) will be accountable for and therefore need to argue for. Further, it is unclear how contribution to the communal tools and communal database will count for professional contribution and establish the value of each person or group's accomplishment. This may also change the balance between competition and cooperation, which has defined relationships among researchers, and the device for distribution of rewards and opportunities. In many ways, the developments being observed in the case of the open data notebook movement resemble some of Joseph Priestley's proposals made for scientific communication two and a half centuries ago, driven by a communitarian, democratic, millenialist philosophy, relying more on communal cooperation than individual achievement (see Bazerman, 1991). Indeed, all of the cases in the first half of this volume contain elements of Priestley's vision, which included advocacy of a less formal and less distant style; greater recognition of paths of development, false turns, and mistakes; fuller sharing of data and methods; critical inspection of machines and procedures; less focus on star achievers and greater recognition that knowledge comes from taking into account the experience of all; greater focus on sharing of reasoning and experience in

more narrative publications; and less attempt to create irrefutable arguments. He argued against the hoarding and hiding of unique methodological and intellectual resources that accumulate advantage for one group over the other (as evident in his faulting of Newton for being like the one who paints the ceiling of a great cathedral and then removes the ladder so no one can re-create such a magnificent accomplishment). Priestley, just as the *OpenWetWare* site, provided means for the recruitment and training of young scientists and the collaborative development of common standards, methods, and modes of interpretation. While some of Priestley's vision had been incorporated in the intervening years (such as in expanded citation and review of literature practices that create narratives of the field's communal advance and collaborative construction of knowledge), the competitive empirical argument for claims became the basis of an encapsulated form rather than the more open-ended inquiry narrative Priestley espoused. Whether the Internet will provide robust tools and Science 2.0 philosophy will be robust enough to push science further along communitarian paths and forms of presentation will be interesting to watch.

The democratic engagement of wider publics in science and the textual means for accomplishing public engagement are most directly the themes of the latter six studies in this volume. While such cases might be viewed as a continuation (through more robust, accessible, and interactive means) of prior science popularization, social changes as well as changing affordances of the technology are producing higher levels of engagement—with possible consequences for further significant reconfiguration of communication. The case furthest on the popularization spectrum is Wardlaw's study of the NPR weekly broadcast Radiolab (with a radio listenership of about one million and an additional podcast download audience of 1.8 million weekly). Comparing a popular science book on the same topic as on one Radiolab episode, Wardlaw finds the show emphasizes the emotional potential of science stories as a form of entertainment over the transmission of scientific content. The display of emotionally exciting wonders for popular consumption goes back at least as far as Renaissance wondercabinets and continued through Barnum's 19th century museums of spectacles. Ripley's Believe it or Not still survives in museums in tourist districts. Although Wardlaw emphasizes the emotionality as a corrective to theories of more sober science popularization, what I find most notable is the way the emotional entertainment is designed for an already educated audience, ready to be amused by playing with science; further, the segments of the show are sequenced to bring the audience into deeper engagement with the topic of the week. As Wardlaw comments, the episode "initially invokes a visceral disgust for parasites only to later instill wonder and admiration for their complexity." Further, based on the specifics of the episode Wardlaw cites, it appears the visceral elements of the show achieve their amusing over-the-top effect by an ironic and knowing stance. So the show allows the sophisticated audience to indulge in emotions they in a sense know better than as a prelude to more serious and even more engaging content

appropriate to their level of education and sophistication. Play with scientific knowledge turns into scientific knowledge as the ultimate play.

Pigg, Hart-Davidson, Grabill, and Ellenbogen in their study of *Science Buzz*, an interactive science popularization blog run by a science museum, point to the way a nonscientific but educated audience engages science through practical reasoning in order to solve ordinary life problems. As the college-educated science-literate population has grown and continues to grow, we can expect more serious and more extensive public engagement in science for more and more life issues. This is a process that has been building at least since the 19th century, but which got an enormous boost in the postwar expansion of higher education and the post-Sputnik focus on science education. The extensive and in-depth resources that can be made available on the Internet, rapid communication of science news afforded by the Internet, the concern of scientists themselves to engage publics, and the Internet's opportunities for interactivity are perhaps supporting another moment of growth in public engagement of science to address practical challenges of life, consumption, and health.

QA: Are we going to have to update this paragraph since it it going to be published in another book first?

Fahnestock documents the complexity of educated audiences seeking information on the Web and the multiplicity of resources by which information is now being made available to meet multiple needs. She examines the reporting of the discovery of adult neurogenesis and the attendant controversy in a range of websites from open access scholarly journals (with new supplementary and simplified summaries for the public), the official website of scientific organizations, Wikipedia, science news sites, health forums, patients groups, and the health and wellness industry websites. She finds that the variety of resources, the speed of dissemination of findings through the tiers of representation, and interactivity support engagement and the varied uses of the many groups. But she also finds that controversies refract through varied interests and may remain active long after consensus is reached among scientists. In short, scientific debate takes on a life of its own among the many interested constituencies who recognize a stake in scientific findings.

Increasingly sophisticated citizens ready to look for science to reason about life problems also form the audiences for the kinds of interactive disaster information websites documented by Kostelnick and Kostelnick. These websites, using multitiered visualizations, allow users to investigate past disasters, track the impact of current disasters, and gain information about possible future ones. The interactivity allows users to study specific locations with which they have an interest, to pursue the data in great detail, and to customize the interface around their concerns. Because of the potential impact of disasters for website users and the strong empathetic emotions that might be aroused in constructing the effects on others, these websites may arouse great engagement and emotions, despite the factual documentary character of the presentation. The interactivity and navigable data depth afforded by the technology provide an interactive space for people to pursue their engagement and interests, drawing them further into scientific knowledge.

Wynn examines visual representations of extremely exigent cases of disaster information concerning nuclear power plant disasters for real-time evaluation of threat and action decisions. In comparing older print media (*New York Times* and *Washington Post*) representation of the unfolding Three Mile Island and Chernobyl disasters and aftermath with recent Internet representations of a traditional news outlet (*New York Times*) and a citizen-based website (Safecast), he finds that representations vary according to material, sociopolitical conditions, and rhetorical agendas, as one might expect. But he also finds that technology matters, with the Internet having a transformative effect. Part of that effect is in the multilayered display of information, allowing greater depth and combination of information, which can be pursued according to readers' needs and interests in both the traditional news outlet and the citizen-based website. An even greater effect of technology, however, is the communicative and collaborative power afforded to noninstitutional actors to create and distribute representations that reflect the needs and interests of citizens' groups rather than of institutional actors. This collaboration extends even to the collection of scientific data. In the wake of the Fukushima earthquake, tsunami, and nuclear power plant meltdown, the team that produced Safecast as an online radiation mapping tool collaborated with a citizen-science group wanting to provide citizen information. The initial motive of data visualization soon turned into citizen data gathering, as more local and changing data were needed in the turbulent, evolving disaster. Standardized inexpensive Geiger counters were designed and distributed, and reporting tools created. Also, to serve needs of individuals assessing personal risk, richer and deeper visualization tools were created, including contextual information, so one could locate that data by on-the-ground landmarks rather than just geographical coordinates.

In a related chapter, Kelly and Miller look further into the citizen needs for detailed, accurate, and up-to-the-minute data about the Fukushima nuclear meltdown and fallout. They examine the role and evolving content of the multiple platforms used to meet the exigence at different moments in the evolving situation, including Twitter, science blogs, Wikipedia, and Safecast. They also note how the need for data reorganized the flow and control of information from scientist-originated to citizen-originated. As they note, the citizen data-gatherers were not organized as teams working under the supervision of scientists who vetted and controlled their work, but were independent operators, motivated to contribute to the common good. Nonetheless, the distribution of standardized Geiger counters served to discipline and control the work of the citizen participants and assure the production of reliable data that could be coordinated and compared with the data reported by others. Well-designed and reliable technology appear in some focused circumstances to obviate the need for extensive training and control. This may have important consequences for citizen participation in science in the future.

Citizen participation in science around issues important to their life has been a growing movement since the early days of opposition to nuclear testing, when alliances were forged between citizen groups and scientists to make available information that would serve the needs of citizens. Further, in this early movement, citizens became involved in research by contributing baby teeth to document the increasing incidence of radiation in children's bones, though these samples were still to be collected and analyzed by trained scientists (see Bazerman, 2001). The environmental movement, which was a direct descendant of this earlier movement, continued to engage people in collecting data and in fact to become more trained as scientists to pursue policy-related inquiries. This engagement of science with citizen interests and citizen participation transformed the ethos and goals of some existing specialties and helped form others. But the reach, speed, and interactivity of the Internet has greatly expanded the potential for building citizen science and creating productive research collaborations between scientists and citizens when there is public exigence.

Cases in this volume indicate multiple social forces and dynamics are rearranging scientific communication, particularly with respect to the locus of control over postpublication evaluation of scientific; the broader cooperative production of data and forging of greater collaborative ethos among formerly competitive scientific teams; and of engaged, educated, informed citizenry asserting its needs for science, becoming a market for science, and even collaborating in the production of science for its own needs. Nevertheless, while some chapters in the volume take examples from open access academic publishing, this volume does not examine how digital production and distribution through the Internet are changing the economics of academic publishing, particularly in a time when university libraries are challenged financially by corporate acquisition and marketization of traditionally boutique academic publishing that was culturally congruent with academic culture. All this is challenging the information chain that supported the emergence of the encapsulated scientific article. How disruptive these new dynamics will be for already existing forms of scientific communication is uncertain. What does seem certain is that there is a proliferation of new communicative forms and forums to forge new relations, serve new needs, and exploit the potential of the Internet. Whether these emerging communicative channels and dynamics will rely on and reinforce the encapsulated article as a core reference point, whether they will displace it, or they will push it in new directions remains to be seen.

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