Online Science Communication and Public Science Literacy

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Online Science Communication Effects on Public Science Literacy

The conceptual framework of the public's understanding of science is considered by Einsiedel and Thorne (1999) to be divided into two broad areas: (1) the public's scientific literacy, and (2) an interactive science model. Both conceptions are viewed as broad portraits by which science's mass communication conceptually evolved and scholars have argued that the scientific literacy and interaction models are not mutually exclusive (Logan, 2001). Research has shown that a large number of American adults are scientifically illiterate (Maienschein, 1999), leading some science communication scholars to conclude there is an overall problem in science communication (Ziman, 1992). This paper seeks to explore science communication and the public's illiteracy in a theoretical context and attempts to develop the conception in the context of scientific blogging and online science journalism communities. The paper will examine a convergence of two-step flow and risk agenda setting, with science blogs as mediating objects in the boundary layer between scientists and the greater public.

The two broad areas encompassing the framework of the public's understanding of science exist with a conceptual framework of science communication. The public's science literacy model is implied to be pedagogically based, deriving from a flow of knowledge from the scientific community to the public, disseminated by the media (Einsiedel & Thorne, 1999). The scientific literacy model research also encompasses areas of inquiry regarding: sources of science news, transformation of research into popular science, gate-keeping, agenda setting, and the impact of science communication on science policy, public affairs, and public opinion (Logan, 2001). A portion of science communication initially derived from health communication campaign research in the 1970s (Bandura, 1977). Social learning model in a health

communication context conceived news as conveying targeted messages from health care providers through communicators to health care recipients that increased knowledge about specific health habits. Researchers at Stanford showed this increased health knowledge was found to have a direct influence on the lifestyles of subjects, and provided an opportunity to assess the linear science communication flow (Farquhar, Magnus, & Maccoby, 1981). Science literacy by publics, in light of the personal and societal impact, could be considered an inherently transformative, highly personal experience (Tobey, 1971). Indeed, scholars extended science literacy's influence to elevating human confidence and capacity to create a modern, industrial, self-critical, tolerance, and democratic society (Logan, 2001).

An interactive science model acknowledges uncertainty embedded within the scientific enterprise, and that science cannot be separated from its social and institutional connections. The interactive science model suggests the flow of science knowledge is not always from experts to laypersons, but could be considered multidirectional (Einsiedel & Thorne, 1999). Also within the interactive model, science knowledge is conceptualized as less certain than within the science literacy model. The emphasis is less on overall information dissemination, but more on the overall informal conversation, which is shared and multidirectional (Einsiedel & Thorne, 1999). This conversation typically is established among citizens, scientists, politicians, government and business officials, and journalists. This interaction between publics is considered a vital first step in rekindling public engagement, interest, and comprehension of science. Putnam (1993) describes a social malaise in his book, *Bowling Alone*, to be also affecting the perceived credibility of social institutions as well as major professions (science, medicine and journalism). Yankelovich (1991) and more robustly Carey (1989) prescribed a dialogic approach in order to

foster a live interaction between scientific experts, policymakers, scientists, and representative citizens.

Science Understanding Problem Models

Ziman (1992) typologically categorized the problem of the public's understanding of science in three ways: a deficiency model, rational choice model, and a context model. A deficiency model suggests that widespread ignorance is a problem because scientists in democratic societies depend on public goodwill for funding and support. Evidence shows that scientific illiteracy in major democracies is widespread (Hartz & Chappell, 1997), and mistrusting attitudes toward science may be growing (Yankelovich, 1982), thus this overall lack of understanding stifles scientific progress. Logical problems hinder the deficiency model, such as the lack of a clear explication of science itself, as it is not a "well-bounded, coherent entity, capable of being more or less understood" (Ziman, 1992). The second perspective, the rational choice model, asks the question of what essential scientific topics people need to know in order to inform their role as citizens. A conceptual limitation inherent in this arises when conflicts among scientists over findings and theory perplex the general public, leading to an erosion of public trust in science (Ziman, 1992). Finally, the context model requires understanding of the context of scientific knowledge and how difference people put it to use. Scholars such as Logan (1999) and Ziman (1992), have found that scientific communication scholarship could benefit from adopting the context perspective of the problem of scientific illiteracy.

The problem of scientific literacy itself has been illustrated in multiple studies. For example: two thirds of scientifically attentive publics cannot pass a relatively minimal test of science literacy (Miller, 1983), and fewer than half of the respondents to a national survey in

2000 could correctly answer basic scientific questions (National Science Board, 2000). Stephenson (1973) suggested that researchers in science communication should utilize two audience-based approaches to investigate science understanding by the public: (1) what citizens know about science, and (2) how citizens perceive science. The first research orientation attempts to assess the cognitive impact of science reporting after persons are exposed to science news. The second seeks to anticipate how audiences might respond to future messages through better understanding of the audience attitudes about science, their attentiveness to public affairs, and other issues. Such research orientation also assumes a science communication consumer represents a complex blend of prior knowledge, attitudes and habits, or more broadly science schema. This predisposed schema affects how persons perceive the credibility of science and science news, the extent to which individuals are interested in science, likelihood to consume further, and potential recall of concepts within science stories (Stephenson, 1973).

The attitudes of individuals toward science are also considered complex. Angell (1996) has argued that the United States is in the midst of a groundswell of anti-science feeling, specifically citing a renewed opposition to the teaching of evolution in public schools as an example. Surveys indicate that public belief in the capabilities of science to solve problems has diminished while simultaneously showing that public distrust of science or viewing science as dangerous and unmanageable has increased (National Science Board, 2000). Public attitudes of science may be influenced by the tonality of science coverage as well, with content analyses showing moderate evidence of news tones correlating with public attitude (Logan, 2001). These individual characteristics, as well as direct and indirect pressure from multiple levels of

organization and society determine the constraints that science journalism faces (Shoemaker & Reese, 1996).

Science Journalism Agenda Setting

The agenda set from science communication can be delineated as the prominence of science issues in news media that can affect the salience given to those issues among the audience (McCombs & Shaw, 1972, 1993). Because science information professionals (science journalists, organizational public relations) have most often been trained as journalists, their degree of formal education in science is little to none. Weaver and Wilhoit (1996) found that journalists with a degree in mathematics, physical or biological sciences comprised less than three percent of overall journalists. However, due to the level of specialization required for science journalists, their level of science education is generally higher than their general news peers (Logan, 2001). Science journalists have been shown to have different values than regular journalists, favoring alternative formats to hard news to allow for more effective science communication (Friedman, 1986). Numerous studies have shown that: AIDS coverage at an elite newspaper influenced perceptions of the disease as a legitimate social issue (Baker, 1986), increased early detection usage for colon cancer after coverage of President Reagan's colon cancer surgery (Brown & Potosky, 1990), and increased public awareness of climate change from media controversy (Spoel, Goforth, Cheu & Pearson, 2009), to name a few. In those and other instances, the influence science communication has on the public's perception, comprehension and behavior was shown. The literature's prevalent assumption is that high levels of science knowledge correspond to favorable attitudes toward science (Schibeci, 1990), although there are relatively few data to support a relationship of science knowledge and

salience. Logan (2001) has speculated that those who possess narrow or broad opposition to scientific research efforts might actually possess greater levels of understanding of science and the scientific method than to nonattentive publics.

Science Blogs as Boundary Layer

Science blogs have been conceptualized as a boundary layer between the science community and the public (Shanahan, 2011). Considering the inherent complexity within the topics provided by science communication, Bucchi (2008), argued that a level of translation and mediation have become the dominant models of science dissemination, which is in agreement with a science literacy model. Within this framework, a linear model of communication develops, from the source community, which is made up of science and scientists, to the audience community, and is conceptualized in this paper as a science audience consumer (Shanahan, 2011). Shanahan (2011) further argued that blogging provides a potential chasm to the linear transmissionist or traditional science literacy model, and this disruption to the potential model was explored through the lens of boundary phenomena.

Science blogging has been examined by Kouper (2010) and Colson (2011), as a potential channel for science communication. Kouper's (2010) findings indicated that the authors of science blogs are predominantly related to science, yet with a diversity in the nature of the relationship. Some science bloggers are graduate students in a particular discipline of science, for instance physics or microbiology. Other science bloggers are lecturers, researchers, and professors from particular disciplines as the graduate student bloggers were. Still further, some are science writers and journalists. The diversity across science blogs can be explained from the realization that the authors themselves are remarkably diverse. Regardless of the diversity, what

is a commonality among the science bloggers is a specialization of interests, knowledge, and appreciation. Colson (2011) remarked on the tenuous relationship between journalism and scientists, with scientists considering journalists to be oversimplifying science, and journalists considering scientists to be reticent. This specialization is often limited to specific audience tailoring of the science blog. For instance, a science blog targeted for a wider audience would be a more "popularized", while a blog targeted for fellow scientists within a discipline would be significantly less "popularized".

Boundaries are a theoretical framework that is concerned with differentiation and inclusion about insiders and outsiders, and the interaction between them. Science blogging as a boundary would be conceptualized as a direct border between the science community and the public, or within science communities (Shanahan, 2011). Boundary objects are conceptualized as something that people act towards or act with, with examples such as theories, published articles, and books to name a few. Interaction in this conceptualization, would be any object that two bordering groups could utilize (Shanahan, 2011). For example, the science blogging community can disseminate an object of scientific research literature to the public. The object would then be utilized simultaneously by the public and the science community through the border of science blogging. Some science bloggers such as Carl Zimmer have explored this interaction between scientists and the science readership through blogs by directly fostering discussions between the two. The boundary was determined to be more conceptually challenging considering that individual posts most often changed the topic from post to post. Indeed, Shanahan (2011) admitted that blog posts may be situated at a boundary position possessing interpretative flexibility and stable identity, although they do not serve the collaborative purposes

conceptualized for boundary objects. Considering the specific nature of science blogs (topic complexity and comprehension), Shanahan (2011) introduces the concept of a fluid boundary layer. For the purposes of this paper, a fluid boundary layer is considered a place where members of social groups are both present and have an influence on one another.

Scientist/layperson Interaction

Scientists' attitudes toward such a direct interaction has been an area of science communication research in order to investigate the efficacy of direct scientist, layperson interaction, and to gauge scientists' overall opinion of such a fluid boundary layer interaction (Mizumachi, Matsuda, Kano, Kawakami & Kato, 2011). Their findings indicate that scientists are overall reticent to participate in such a direct online "science cafe" communication, specifically five major factors were identified: (1) troublesome or time consuming, (2) pressure to be an appropriate science representative, (3) outside the scope of their work, (4) could not perceive any benefit, and (5) apprehension about dialogue with the public (Mizumachi, Matsuda, Kano, Kawakami & Kato, 2011). All these factors represent intrinsic barriers to dialogue between scientists and the public, and the findings from the study performed by Mizumachi, Matsuda, Kano, Kawakami & Kato (2011) are congruent with other science communication research into scientists' attitudes toward direct dissemination of science information. However, research has shown that public attitudes toward scientists were more positive following a direct dialogue with scientists. That finding was limited to the public's attitude, and not expanded to their overall science understanding or science literacy (Zorn, 2010).

As briefly discussed earlier, the implications of direct scientist/layperson interaction have been examined in science communication research. Using human biotechnology as the direct

topic to examine direct scientist layperson dialogue or interaction, Zorn (2011) found that dialogue fostered attitudinal change, as well as providing a convergence of scientist's attitudes and laypersons. Zorn's (2011) results provided evidence for dialogic proponent's claims, that participation in a dialogue contributes to learning and an increase in shared meanings or a "shift of mind" as it was referred to by Ellinor and Gerard (1998), in participants views of themselves, others and the topic of discussion. Such direct comparison of pre-dialogue versus post-dialogue understanding and attitudes are examinations of the participation across the boundary of science and the public through the boundary object of science blogs.

This theoretical exploration of a boundary between scientists and science readership represents not only a reconceptualization of the theoretical framework of science communication, but a nexus of diffusion of innovation, fluid boundaries, and agenda setting, with agenda setting capabilities of science blogs being investigated for this paper in the context of risk salience and science attitudes. This paper's discussion will integrate the conceptual frameworks of diffusion of innovation and agenda setting particularly in science communication by examining the implications of online science implications to science literacy and salience. Also discussed are limitations to such theoretical perspectives, as well as suggestions for future research.

Discussion

Lowery and Defleur (1995) states that a two-step flow of information is formulated as a flow of information from print and radio to opinion leaders and from those opinion leaders to less attentive audiences. This secondary movement of information and influence from interpersonal networks among members of the audience is a key conceptualization with

numerous implications. When science communication is performed through blogs, those blogs act as opinion leaders in the conceptualization. The readership in this conceptualization is niche, as is the communication itself as previously discussed, and this provides the science blogging community an important role in the dissemination of information from the scientific community to the public. Discussed later, the values (risk perception) of the interpersonal communities must be closer to homogeny, as individuals who are close and interdependent on one another tend to demand a higher degree of conformity with each other.

Nisbet and Kotcher (2009) examined the role of opinion leaders in disseminating climate change campaigns to the public. In a fragmented audience environment, self-designated opinion leaders were examined on the basis of a criteria derived from Katz (1957): who one is-- individual characteristics, values, schema; what one knows-- degree of knowledge or expertise about a particular issue (science literacy); whom one knows-- the number and distinction of contacts that individuals possess. According to this criteria, Nisbet and Kotcher (2009) developed six climate change specific traits of opinion leaders from the work of previous scholars on self identifying opinion leaders: issue-specific opinion leaders, influence as personality strength, Roper ASW's influentials, product or behavior-specific opinion leaders, communicative early adopters, and market mavens. Across blogging topics, the study also found that bloggers have many traditional traits of opinion leaders. Within the context of a network mediated environment, a science blogger acts as a virtual opinion leader influencing networks of people (Kouper, 2010). They act to set the agenda of their readers on issues such as climate change, but act to set the media agenda as well, engaging in what Brosius and Weinmann (1996) considered a multistep flow of agenda setting. In this specific context, bloggers are used as both a science disseminating

forces for the greater public, setting reader agenda, but also as science agenda setters for the media.

As previously discussed, the boundary between the scientific community and science audience community provides for opportunities for science communicators to act as agenda setters in both a first and second level. Considering the niche characteristics of the audience of science blogs, the audience itself could be considered opinion leaders, acting as a mediators to the general audience which is less attentive to science communication. In this way, not only does the science blogger act as an opinion leader, as previously discussed, but the audience then further promulgates science communication they encountered in the online setting to the greater public (Shanahan, 2011).

After the September 11th attacks, the U.S. was exposed to a series of anthrax attacks in October sent through letters containing anthrax spores. These attacks had strong repercussions on science regarding science communication mechanisms and science's public image (Montani, 2006). Montani examined the salience of bioterrorism topics in light of the attacks, finding that such a crisis or risk event awakened the public and media interest in bioterrorism. Within popular science journals published after the anthrax attacks, bioterrorism articles featured politics, ethics, and economics dimensions to greater degree than previously found in science communication. This finding was also extended to mainstream newspaper articles examined by the researchers, finding that such diversity in social actors and story narratives fostered within this social and crisis context fostered more interest and understanding. Scholars have examined such a crisis context relation to knowledge gap and found the concepts to be directly related. Indeed a study, on apocalyptic rhetorical narratives within climate change communication indicated that such

value laden crisis communication raised salience of climate change and its impact (Spoel, Goforth, Cheu & Pearson, 2009). The apocalyptic narrative provided a narrative structure to function as a powerful resource for integrating the ethos, pathos, and logos modes of proof into politically as well as ethically and technically compelling science stories.

Risk factors in science communication require some expansion in this article. Communication such as health, bioterrorism, and climate change carry an inherent risk variable within the context of the communication itself (Bennet & Jennings, 2011). For the purposes of this paper and in line with Bennet and Jennings (2011), science risk are considered those risks perceived through science, perceived directly, or virtually. For example, a risk perceived through science would be something like cholera, which is microscopic and requires scientific knowledge and equipment to perceive and understand. For those risks perceived directly, are the personal empirical risks that individuals have direct perception and understanding of. Virtual risk may be real or para-authentic, and as an example consider the "uncertainty" of the science community in regards to some findings. It has been argued by science communicators that the public craves certainty and cannot cope with the provisional nature of scientific knowledge (Bennet & Jennings, 2011). However, this argument fails to recognize the variance in perception from science reader to science reader. The risk overall impacts the science communicators by raising the level of attentiveness and understanding as previously discussed, and by adding a value to the communication, perhaps not easily expressed by science.

Continuing this convergence of risk into the science communication conceptual framework, Corley, Ho and Scheufele (2011) examined the value predispositions of public and experts' attitudes toward nanotechnology. Their findings indicate that the public perceive science

as having greater risk and lesser benefits than experts' perceptions, and this risk perception extended to the public's support for economic support for sciences. Methodological weaknesses within many studies of the relationship between expertise (scientific knowledge) and risk judgement may have attenuated the true effect size. Defining the groups to examine provided one part of the problem in methodology, and another part involved controlling for social demographic factors. Regardless of the methodological difficulties, this difference in perception between lay and expert acts to make the public more concerned with science communication, more skeptical, but more attentive. It was also found that the interaction between science media use and scientific status and the interaction between trust in scientists and status on perceived benefits were significant. The assertion contained in this finding is that the public rely on heuristic cues to a greater extent than did the experts when making benefit judgements (Corley, Ho & Scheufele, 2011).

Developed earlier, the boundary object of the online science community, specifically science blogs, are utilized to bridge the boundary layer between the scientific community and the public. It is at the boundary objects of online science blogs that exists the convergence of the two step flow of information and agenda setting. Because scientists and science communicators are able to communicate directly with their science readership, they are able to act as direct agenda setters and opinion leaders in a two-step flow. Further, considering the niche appreciation of science that the audience contains, science readers act as opinion leaders themselves. In line with the previous model of interactive science communication, blogs provide multidirectional interaction. Further developed from this paper, blogs provide a confluence of opinion leader two-step flow capabilities and multidirectional agenda setting. Within this convergence, this paper

examined the possibilities for an increase in awareness and comprehension. This paper argues that science agenda setting is inherently value based in both cultural and personal terms. Due to this, the salience of value based science topics are potentially raised, for example climate change, biotechnology, and evolutionary topics.

At such a boundary, findings (Zorn, 2010) have determined that interaction between scientists and laypersons have not only influenced the public, but that laypersons are also influencing scientists. What scholars Ngu, Vu, and Gehrau, (2010) have termed an "agenda diffusion," such interpersonal communication influence the overall agenda that is being diffused from the media. In this case, a blog post raises the salience, and then the flow of information from science readers to non readers, and further back to the scientists themselves to adjust the overall agenda and communication due to the influence found by Zorn (2010). Because of the capabilities of online science communication, specifically interaction, a confluence of agenda setting and two-step flow, and the value laden aspects, this paper posited that opportunities for greater shared understanding between the boundary layers of scientists and the general public are burgeoning due to the unique capabilities of online science communication.

Limitations

In a recent commentary to the *Journal of Science Communication*, Bell (2012), contests that science blogging has done little to change the larger mosaic of science writing. Arguing the science blogging community is distinct from professional science journalism, the cultural and social distinction of the two delineates that blogging is less instrumental in overall impact on science comprehension and public appreciation. Aspects such as anonymity in an online setting differentiate some science bloggers from mainstream science journalists, although this

differentiation may not lead to a decrease in credibility. Further, the hypertext nature of the web means that the blogosphere is connected in a larger network, and this networked environment strengthens science communication overall. However, Bell argued that this hypertextuality is underused, or in a rudimentary stage. Indeed, very few articles discussed any potential for social media utilization in science communication. The theoretical limitations of this paper fall in line with the criticism of Bell, that the online technologies are still in rudimentary stages of research and convergence professionally. However limited the scholarly research is, science blogs have been recognized as providing an opportunity for reflexivity, or a self examination. Such reflexive communication was not examined in this paper, but could act to improve science communication through retrospection as this reflexivity could be better facilitated through audience interaction, such as blogging comments and greater discussion (Bell, 2012). However valid Bell's commentary is in regards to the impact of science blogs within the larger framework of science writing, her comment does not appreciate the impact of science blogs on the public's science literacy and salience. Her comment is limited to the larger mosaic of science writing, encompassing published science books, popular science journalism, and similar non-blog publications.

Suggestions for Future Research

Future research into the effects of online science journalism on the science literacy of the public should begin by asking the implications of science journalism in the context of social media. Direct methodologies to test scientist/science reader interaction in relation to science salience and awareness. Discussed in this paper are also the moral values inherent in science topics, which provides another avenue for science communication research in an online setting.

Does interaction with scientists (experts), alleviate public concerns about science and technology? Also, does this alleviation have any effect on the overall public awareness? Further, aspects of public awareness in relation to the online science journalism community have not been fully explored. For instance, what aspects of science blogging could facilitate a greater appreciation of science, which could lead to increased funding or public support?

This paper is a theoretical exploration of online science communication's impact on science literacy. Further research should consider not only the agenda setting and diffusion nexus, but also the readership predisposition to science messaging. Topics such as climate change have become politically charged in recent years, and an exploration of the audience predisposition and psychological dynamics could help have explanatory power in regards to the reluctance of some of the public to readily accept and appreciate scientific findings and research.

Conclusion

Science illiteracy has been shown to be prevalent throughout society, with science communication scholars acknowledging this prevalence as a problem. Ziman (1992) identified broad views of the problem of science illiteracy: a deficiency model, rational choice model, and a contextual model. All three emphasized that a lack of science understanding hinders social goals, scientific goals, and individual level lifestyles. Due to the increasing importance of science and technology to our society, this paper discussed ways of attenuating the knowledge gap through online science communication.

This paper analyzed science blogging and online science communication through numerous theoretical contexts. An initial conceptualization of public science literacy was explicated, as well as an exploration of the overall problem inherent in science illiteracy. Science

blogging was conceptualized as a specialized communication form, targeting audiences ranging from niche to wider, more popular ranges. Further science blogs were examined as a boundary layer between the science research community and the science audience. Through this lens of boundaries, the concept of a fluid layer of communication was developed, in which scientists directly impacted the understanding of the readership through interaction facilitated in the virtual setting of the online community. Further development of this convergence of interaction led to the concepts of two-step flow and agenda setting being discussed. Science communication in an online setting, considering the specialization aspects discussed, is theoretically intermeshed with the specific opinion leaders specialized communications and their use of direct diffusion to less attentive groups of the public. The agenda-setting capability of science blogs combined with this diffusion converges at the online blogosphere, where discussion and interaction lead to dissemination of science knowledge and a greater understanding. Adding a moral complexity to the agenda setting effects was also discussed as potentially lessoning the knowledge gap within the public related to those science topics that have intrinsic value. This paper provides evidence of increased salience and science literacy through the utilization of science blogs as bridges from the science community to the general public. At such bridges, this paper found that a direct scientist/layperson interaction increases the audience's appreciation and understanding, as well providing an opportunity for both the science communicator and the audience to act as opinion leaders according to Katz's (1957) criteria, and thus theoretically disseminating further interest and understanding of science.

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