

*This article provides a conceptual history of science mass communication, which is seen as divided into the scientific literacy and interactive science traditions. The origins of the ideas that underlie the scientific literacy and interactive science traditions, as well as some of the issues researchers have raised, are introduced. The author argues the two traditions are not mutually exclusive, although the interactive tradition is a response to the applied problems within the scientific literacy model. It is argued that the pace of research might be accelerated if there were a more comprehensive collaboration among science communication, health communication, and risk communication scholarship.*

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## ***Science Mass Communication***

*Its Conceptual History*

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*In a recent essay, Einsiedel and Thorne (1999) found the underpinnings of previous research about the public understanding of science is divided into two broad areas: (1) the public's scientific literacy and (2) an interactive science model.*

Einsiedel and Thorne (1999) explained that studies representing the scientific literacy model “suggest that knowledge of particular basic scientific ideas and concepts is required for people to function well in a variety of cultural contexts. Scientific knowledge within this framework is generally portrayed as fixed and certain” (p. 49). In terms of mass communication, the scientific literacy model is implied to be pedagogically based, a flow of knowledge from the scientific community through the press to citizens. In contrast, the interactive science model “takes as a given the uncertainties embedded in the scientific enterprise and the idea that science cannot be separated from its social and institutional connections” (Einsiedel and Thorne

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1999, 50). Besides acknowledging uncertainty and a science-society connection, the interactive science model suggests the flow of science knowledge is not always from experts to laypersons and implies it might be more shared or multidirectional.

Both models, or underlying conceptions, of how science is communicated to the public are seen as rough “portraits” of the process by which science’s mass communication conceptually evolved (Einsiedel and Thorne 1999).

As Einsiedel and Thorne (1999) suggested, science communication’s research models and traditions provide insights into the history of the field and its future direction. By reviewing them, the foundations of the field and its sense of direction are clarified, and the field of science communication’s links to related fields (such as health and risk communication) and the history of mass communication research become more apparent. While Einsiedel and Thorne’s discussion continued in terms of how to communicate uncertainty to different publics or audiences, their scientific literacy and interactive models are used more broadly here to compare how research about science’s mass communication is undergirded, the enthusiasms of contemporary researchers, and their topical range and future challenges. Since a comprehensive literature review of research findings is included elsewhere in this issue of *Science Communication* (Weigold 2001 [this issue]), this article provides a conceptual history of science mass communication, introduces the ideas that developed each model, and discusses some of the subsequent issues researchers raised.

The scientific literacy and interactive models are seen as a foundation to explore research traditions because each begins with a similar challenge regarding improving the public understanding of science, while each raises separate, initial conceptual assumptions that foster different research directions and insights. To pose a comparison, the scientific literacy tradition first will be introduced with an emphasis on its initial assumptions and the range of research topics about audiences, sources, messages, and channels that emerged from this model. Since the historical origins of the scientific literacy tradition are rarely discussed in the literature, some attention is paid to its development during the first thirty years of the twentieth century. The conceptual roots of the transition to the interactive model in the 1980s are discussed, as are the presumptions embedded in the comparatively new and evolving interactive science tradition.

This article argues that the two traditions are not mutually exclusive, although the interactive tradition is a response to the applied problems within the science literacy model. It is argued that the pace of research might be accelerated if there were a more comprehensive collaboration among science communication, health communication, and risk communication scholarship.

The terms research “model” and research “tradition” are used interchangeably, even though a “model” sometimes is interpreted as a diagram of research constructs while a research “tradition” sometimes refers to a much broader conceptual direction. Unlike scientific areas that Rowan (1999) described as textbook science, the subdiscipline of science mass communication and the broader field of mass communication research represent emerging, pioneer, and somewhat unsettled social sciences (McQuail 2000; Severin and Tankard 1997). As a result, both the narrowed topic of science’s mass communication and its larger disciplinary context provide rough models partially supported by preliminary qualitative and quantitative evidence that, in aggregate, converge into traditions or broad research directions. The ideas within this article, I hope, explore the emerging and dynamic spirit of each tradition and introduce how science communication research has been conceived, is evolving, and might progress.

### ***Scientific Literacy Tradition: The Classical Model and Audience-Based Research***

Unlike many areas within mass communication, the public communication of science originally was grounded in a pedagogical purpose. This section describes how the classical model of science communication evolved historically and how research within the scientific literacy tradition encompassed public understanding and the publics that converge on science. The scientific literacy tradition also encompasses areas of inquiry regarding the sources of science news, how science gets transformed from research results into news stories, and the impact of subtle news editing and writing decisions on science policy, public affairs, and public opinion. These topics are discussed in a separate section below.

Tobey (1971) described the almost-missionary zeal of a few leading scientists during the first thirty years of the twentieth century, who sought to improve the capacity of Americans to make rational public affairs decisions about science and to better integrate scientific knowledge to improve the quality of their lives. Tobey explained that Slossen, Heyl, Millikan, and Hale were dedicated to a complex agenda that included (1) cultivating the idea of lifelong learning for citizens, (2) helping persons live healthier and longer lives by promoting scientific awareness, (3) encouraging support for the scientific method as a strategy for public officials to assess complex public affairs choices, (4) helping citizens and public officials better understand the connection between investment in science research and the United States’ economic future, (5) improving public investment in science, (6) fostering

more interest in science as a career among American youths, (7) enhancing public goodwill and support for science among taxpayers, and (8) nurturing a public will to support science as a nonpartisan staple of national investment in the future of America's economy and culture.

Slossen, Heyl, Millikan, and Hale also believed understanding science represented an inherently transformative, highly personal experience (Tobey 1971). A commitment to the public understanding of science not only provided immediate rewards of improving quality of life and elevating public affairs deliberations but also was perceived as integral to the elevation of democracy, culture, and the evolution of human potential (Tobey 1971). Similar to Bronowski (1973) or Silver (1998), Slossen, Heyl, Millikan, and Hale did not accept arguments that science is deterministic or is dehumanizing to humanistic traditions in the arts and culture, as Snow (1993) delineated a generation later. Besides longer lives, improved public health, and understanding of nature, Slossen, Heyl, Millikan, and Hale, whom Tobey (1971) termed "national scientists," believed the growth of science was tied to what Bronowski later termed "the ascent of man." Bronowski argued that the evolution of science (more than most other historical developments) fostered the advance of democratic national institutions, the growth of major universities, the importance of public education, the growth of the middle class around the world, and an increased confidence for individuals to challenge conventional wisdom and dogma, and that it engendered a humane passion to probe for truth and evidence. To Slossen, Heyl, Millikan, and Hale, science's sociocultural and individual influences surpassed its immediate findings and applications (Tobey 1971). Science's influence, as Bronowski (1973), Silver (1998), and Holton (1993) later maintained, elevated human confidence and capacity to create a modern, industrial, self-critical, tolerant, and democratic society.

From the outset, Slossen, Heyl, Millikan, and Hale also were concerned about the poor levels of public education about science in the United States (Tobey 1971). They believed the public's poor educational foundation was exacerbated by an entertainment-oriented popular culture advanced by the news and mass media (Tobey 1971). While science fiction and reinforcing popular superstitions remained ubiquitous (e.g., the depiction of mad and eccentric scientists in popular fiction), the news and mass media were seen as providing minimal exposure to understanding actual scientific findings (Tobey 1971). Tobey (1971) explained how Slossen, Heyl, Millikan, and Hale orchestrated reform by working with journalists to publish news stories about breaking science advances and to provide occasional explanations of science and medical processes, such as how a heart functions or why citizens should care about the then-new Einstein theory of relativity. Some of the

national scientists during the first thirty years of the twentieth century urged news magnates, especially E. W. Scripps, to institutionalize science reporting as an ongoing news beat. Slossen, Heyl, Millikan, and Hale approached newspaper publishers with a vision about how their coverage of science could safeguard the nation's future and generate more credibility for the press (Tobey 1971).

It should be noted that Slossen, Heyl, Millikan, and Hale's ideas were often expressed more in personal letters, speeches, and popular editorials than in formal scholarship. However, Slossen and Downey (1922) proposed an empirically based methodology to demonstrate that the transfer of scientific ideas could increase a person's learning curves and inspire "creative imagination."

Although Slossen, Heyl, Millikan, and Hale's conceptual framework was outlined more than seventy years ago, it represents a classic metaphor for the process and effects of science's mass communication that infused scholarship throughout the twentieth century. Some contemporary publications, notably a book by Hartz and Chappell (1997), propose a parallel view of science's mass communication process and update the social and economic impact of poor public understanding of science plus the relative roles and responsibilities that scientists and journalists share to elevate public understanding. Hartz and Chappell advanced an informal framework similar to the national scientists', wherein a diverse, socially therapeutic impact of science's mass communication is subsumed. Consequently, scientists and journalists are asked to provide leadership to improve both the availability of science news to citizens and the quality of the information the public receives (Hartz and Chappell 1997).

A portion of science communication's classical framework was indirectly adopted by health communication campaign research in the 1970s. Bandura's (1977) social learning model conceived the news and mass media as conveyors of targeted health messages from health care providers through communicators to patients that increased public knowledge about specified health habits. Increased public information was linked to improvements in therapeutic health care behaviors, which fostered more popular appreciation and goodwill for the sources of the messages. A series of studies at Stanford University in the 1970s compared lifestyle habits and cardiovascular knowledge between control and target audiences, and it empirically assessed a portion of the linear classical science communication flow model informally advanced fifty years before (Farquhar, Magnus, and Maccoby 1981). More recently, Wallack (1993) took aspects of the social learning model as a primer for public interest health organizations to generate news media attention and obtain publicity for their health messages. While health communication

literature based on social learning models does not credit or cite the classic science communication model, there are conceptual consistencies between the two disciplines.

Although contemporary researchers adopted alternative models of science's mass communication and adapted the classical science communication model to other purposes, it is noteworthy that for most of the twentieth century, the linear linkages and assumptions embedded within the classical framework were decades ahead of conceptual developments within mass communication research. The early, comprehensive models that projected the impact of sources (scientists), messages (the news media's content), and media channels (such as newspapers, magazines, radio) on readers were not advanced until the late 1940s—more than twenty-five years after Slossen, Heyl, Millikan, and Hale discussed their informal, conceptual framework. Applied to the flow of news, Shannon and Weaver (1949) described a linear process where information (the intent and original content) of news sources encountered entropy (or loss of intended meaning) within messages as they moved from an original source through reporters, editors, news organizations, and media channels to citizens. Westley and MacLean (1957) added the idea that feedback loops between sources, the content and context of news messages, and media channels were essential conceptual components within the same process. Much of the research in science communication during the past thirty years has broadly explored Westley and MacLean's conceptual additions, which are discussed in the next section.

Besides sources, messages, and channels, Westley and MacLean (1957) emphasized that assessing the impact of news on "receivers" (the audience for news—viewers, listeners, and readers) was integral to the assessment of mass communication's social impact. Through the early 1960s, MacLean (1965, 1967) urged mass communication researchers to assess public cognitions (what citizens know about public affairs topics and issues), attitudes (what citizens perceived about news, social institutions, and public affairs), and what is today termed a "conative dimension" (how persons intended to behave on the basis of their knowledge and attitudes). Bandura's (1977) social learning model, which was advanced in the same era, provided a similar three-part division to assess audience responses to health communication campaigns and similarly argued that broader mass communication research should be audience centered. While Bandura and MacLean often are considered pioneers in advocating attention to the audience for news and mass media, Slossen, Heyl, Millikan, and Hale's classical framework embraced the importance of understanding the audience for science about forty years earlier. From its outset, the classic metaphor of science communication placed an emphasis on assessing how well basic scientific ideas and

concepts enabled the public to “function well in a variety of cultural contexts,” as Einsiedel and Thorne (1999, 49) described.

In a series of essays about improving the research about the public’s understanding of science, Stephenson (1973) combined classical traditions with then-contemporary ideas and suggested two audience-based approaches. Stephenson suggested researchers should investigate (1) what citizens know about science and (2) how persons perceive science. The first research direction could assess the cognitive impact of science reporting after persons were exposed to science news and other media content. The contrasting, second research direction could anticipate how audiences might respond to future messages through a better understanding of audience attitudes about science, their attentiveness to public affairs, their attitudes about the news media, and other issues. The second research direction assumed a science reader, viewer, or listener is not a *tabula rasa* but represents a complex blend of prior knowledge, attitudes, and habits. The admixture of prior knowledge, attitudes, and habits forms predispositions toward science and science news. Predispositions affect how persons perceive the credibility of news sources; the extent to which adults and children are interested in learning; possible motivations to read, listen, or watch science news; and potential recall of facts or concepts within a science story. By understanding predispositions and defining any common clusters of predispositions within audiences, Stephenson believed science communicators could better tailor messages to suit different audience needs.

Correspondingly, one contemporary branch of audience-based research in the scientific literacy tradition explores cognitions by testing the public’s science knowledge. Scholars such as Miller (1983, 1987, 1998, 2000) have created literacy scales to assess lay science knowledge that have been applied locally, regionally, nationally, and internationally. The work of the National Science Foundation’s *Science and Engineering Indicators* (National Science Board 2000) enables researchers to compare how much students know about science throughout the United States and around the world and to provide benchmarks to assess improvements (or declines) over time. Efforts such as the *Science and Engineering Indicators* provide a sophisticated, postexposure measure of the impact of science news, which is consistent with the classic model’s rationales to encourage science communication for citizens.

The other branch of audience-based research in the scientific literacy tradition explores audience predispositions. Prewitt (1982, 1983) found an audience segment (based on their knowledge, attitudes, habits, and interests) was predisposed to read, listen, and watch science news, and this audience segment was termed an “attentive public” for science. By studying public

attitudes in conjunction with demographic variables, such as income, education, social attitudes, gender, and socioeconomic status, Prewitt (1982, 1983) and Miller (1986, 1998, 2000) roughly identified audiences that were prone or unlikely to be interested in science news.

Gerbner (Gerbner et al. 1980, 1981, 1986) also described an “inadvertent audience” that is neither attentive nor inattentive to science, health news, or other news. To Gerbner (1987; see also Gerbner et al. 1980, 1981, 1986), inadvertent audiences often heavily scan news and popular culture content on television and form impressions about surrounding society and lifestyle habits by casual and constant exposure to media content. Gerbner (Gerbner et al. 1980, 1981, 1986) argued many Americans believe the prevalence of crime is worse than actual statistics because crime news is reported frequently within the news and mass media without an accompanying statistical context. Television viewers also sometimes ignore evidence about the risks of health-related issues, such as smoking, alcohol consumption, and weight control, and gravitate toward unhealthy behaviors that are unrealistically depicted in popular television programming (Gerbner et al. 1980, 1981, 1986; Signorielli 1993).

Assessment of risk perception further elaborates research about audience predispositions by predicting how a range of specific issues fosters citizen outrage about science and technology (such as whether adults perceive a risk as voluntary, e.g., driving, or involuntary, e.g., living thousands of miles from the Chernobyl nuclear power plant) (Slovic 1987a, 1987b; Slovic, Fischhoff, and Lichtenstein 1993).

Both cognitive postexposure research and predisposition research represent core contributions to understanding science mass communication processes in terms of conceptual development and practice. They continue a legacy to explore the conceptual purpose of science communication’s flow, propose what impact science’s mass communication has on audience knowledge, and help media practitioners and scientists anticipate complex social responses.

Some insights from this research genre also led to an important critique of science’s public communication by Trachtman (1981) and Burnham (1987) (see also Dornan 1990; Hilgartner 1990). Despite a generation of efforts to use the press to inform citizens about science (based on the classic science communication model), Trachtman noted scientific literacy in the United States was declining rather than improving. Trachtman (1981) and Burnham (1987) questioned whether the effort made to elevate the public’s scientific literacy (by working with the news media) was undermining the desired effect. Although neither Trachtman nor Burnham questioned whether the observed problems lie in the classic science communication conceptual

framework, their work demonstrated that science communication's classic framework could be turned on its head. Following Trachtman's and Burnham's reasoning, the classic model could be used to justify less, not more, cooperation between scientists, the news media, and the public. In turn, Trachtman (1981) and Burnham (1987) raised fundamental questions less about audience research than about the classical model's conceptual comprehensiveness. The interest in pursuing alternative conceptual frameworks, which is discussed two sections below, partially may have stemmed from scholars who acknowledged the poor scientific literacy in the United States and a large nonattentive audience for science—but refused to conclude either scenario was a rationale to curtail public communication efforts, as Trachtman (1981) and Burnham (1987) suggested.

***Other Links in the Scientific Literacy Process:  
News Sources, News Messages, and Channels***

Besides audiences, the classic science communication framework (coupled with aforementioned advances in mass communication models) also generated interest in the other links in the process as news travels from scientists through journalists to citizens. Westley and MacLean (1957) noted that comprehensive research about the mass and news communication process demanded attention to the receivers of mass communication (the audience research reviewed above) plus news sources, messages, and channels. During the past forty years, Westley and MacLean's source, message, channel, and receiver model has been broadened to encompass diverse topics such as the influences of a surrounding social climate and culture, prevailing political and economic ideologies, social psychology (how persons assess source credibility and are influenced by group and interpersonal pressures), cognitive behavioral models (how knowledge is linked to individual actions), and life skills (how personal behaviors sometimes are influenced by feeling empowered or capable to respond) (Logan and Longo 1999; McQuail 2000).

Singularly within the area of assessing news "messages," McQuail (2000) found that scholarship has evolved from an emphasis on text to focusing on how editing decisions cultivate public knowledge and health habits, help set society's public affairs agenda, and indirectly frame how persons may respond to the topics discussed within news reports.

Within the broad area that Westley and MacLean (1957) termed "sources," McQuail (2000) noted that scholarship evolved from evaluating source credibility to the complex interactions and professional relationship among journalists, news sources, and other participants in the creation of

news, including public information officers. Within the broad area termed “channels,” the Internet rekindled interest in comparing whether newspapers, magazines, radio, television, or the Internet is ideally suited to convey news and information (McQuail 2000).

As discussed below, the development of science communication scholarship regarding source-journalist interactions, how messages reflect news decision-making processes, and the comparative capacity of different media channels seems to parallel developments within the broader mass communication field. If placed in a conceptual tour under headings “sources,” “messages,” and “channels,” an impressive array of issues regarding science’s mass communication have been raised. This section selectively lists some of the issues science communication researchers have explored within sources, messages, and channels categories, respectively.

### *Some Issues Associated with Scholarship about News Sources*

Within the broad conceptual category that Westley and MacLean (1957) identified as “source,” science communication researchers have explored a range of issues that roughly can be divided into four categories: (1) scientists as sources and resources, (2) journalists and their role in utilizing sources and resources, (3) public information officials as sources and resources, and (4) the science policy climate under which scientists, journalists, and public information officials work.

#### *1. Scientists as Sources and Resources*

Within this subcategory, some of the issues raised include the following:

- Who are the sources of science news (Dunwoody 1986)?
- How and why does news attention gravitate to similar institutional sources, such as some major universities and some refereed scientific journals (Nelkin 1995)? Is this attention linked to stature among scientific and biomedical professionals, the infrastructure capacity and willingness of these institutions to deal with the press, a combination of these reasons, or others (Nelkin 1995)?
- What are the norms, conventions, attitudes, and habits of scientists regarding communication with the news media and the public? Do attitudes shift as a result of good or bad experiences with the press and public (Council of Scientific Society Presidents 1991; Hart 1984; Laetsch 1987)?
- Is communication with the press or public inimical or helpful to peer evaluation among scientists (Dunwoody 1986; Hart 1984)?

- What are some of the characteristics of “visible scientists,” and how does their participation in public communication influence their professional and public standing (Dunwoody 1986; Goodell 1977)? In cases of celebrated visible scientists, such as Carl Sagan, why does high public standing sometimes conflict with professional evaluation (Davidson 1999)?
- When is it appropriate for scientists to decline to work with the press and public (e.g., When do national security and corporate trade secrets eclipse public cooperation?) (Hart 1984; Hartz and Chappell 1997; Laetsch 1987)?
- To what extent are whistleblowers in science organizations, government, and industry necessary to ensure the full disclosure of science news and information (Rowan 2001)?

## *2. Journalists' Role in Utilizing News Sources and Resources*

Within this subcategory, some of the issues explored include the following:

- What are the attitudes among journalists about the professionalism of scientists as news sources (Council of Scientific Society Presidents 1991; Krieghbaum 1967; Perlman 1974)?
- Do reporters adopt some of the norms and values of scientists when journalists are heavily dependent on scientists as news sources (Haff 1976; Nelkin 1995; Perlman 1974)?
- Should journalists honor embargoes issued by scientific journals, science organizations, universities, and other news sources (Haff 1976; Krieghbaum 1967; Nelkin 1995)?
- Do news editors (who often are a step removed from reporter-scientist interactions) tend to be more critical of science and thereby better reflect public (vs. scientific) perspectives and concerns (Nelkin 1995)?
- To what extent do journalists gravitate toward visible scientists and more visible scientific social institutions (Goodell 1977; Nelkin 1995)?
- To what extent can journalists be manipulated by sources within government, industry, public interest groups, and scientific organizational sources to skew coverage toward parochial goals (Angell 1996; Nelkin 1995)?
- To what extent can journalists be manipulated by sources outside of government, industry, public interest groups, and scientific organizational sources, who skew coverage toward parochial goals (Angell 1996; Nelkin 1995)?
- Why is it important for journalists to diversify the range of science sources and resources used in reporting science news (Nelkin 1995)?
- Can journalists and scientists working through a professionally sanctioned infrastructure (such as the American Association for the Advancement of Science and the National Association of Science Writers) cooperatively foster

mutual professional understandings and improve the quality of science communication to citizens (Hartz and Chappell 1997; Nelkin 1995)?

- Is the quality of science news reporting related to the educational background of a reporter (Hartz and Chappell 1997; Krieghbaum 1967; Perlman 1974)?
- When is it ethical for a reporter to use anonymous sources to obtain controversial science information and pursue means such as going undercover to obtain science news stories (Lambeth 1992)?

### *3. Public Information Officers and Their Role as Sources and Resources*

Within this subcategory, some of the issues explored include the following:

- What are the professional roles and functions of public information officers (who work for science and biomedical corporations, public interest organizations, scientific societies, and government) (Rogers 1986, 1997)?
- How do public information officers sometimes work through competing loyalties to the public versus their employer or client? Is the role of a science public information officer to maximize full public disclosure of science news and information (Rogers 1986, 1997; Salisbury 1997)?
- To what extent do public information officers influence the process of science's mass communication by translating science to lay audiences (often through press releases), bringing stories to journalists' attention, and serving as a liaison between scientists, a science-based organization, and science reporters (Nelkin 1995; Rogers 1986)?

### *4. The Science Policy Climate under Which All Sources Work (Scientists, Government and Corporate Officials, Journalists, and Public Affairs Officers)*

Within this subcategory, some of the issues explored include the following:

- Is the agenda of the science topics that are raised as important issues in public affairs a function of competition and negotiation among important social actors, including government agencies, politicians, corporations, public interest groups, scientific societies, and the news media (Hilgartner and Bosk 1988)?
- To what extent do government agencies, politicians, corporations, public interest groups, and scientific societies dominate the agenda of what science topics are raised as important issues in public affairs (Logan, Zengjun, and Fraser Wilson 2000b)?

- Is the tacit influence of major social actors in science policy unquestioned by the news media, and does this reflect a complicity between the press and powerful social institutions (Hardt 1999; Hardt and Carey 2001; Illich 1975)?
- What is the obligation of journalists to lobby for improved access to scientists, science resources, and freedom of information (Hartz and Chappell 1997; Kriehbaum 1967)?

### *Some Issues Associated with Scholarship about Messages*

Within the broad conceptual category that Westley and MacLean (1957) identified as a “message,” science communication researchers have explored a range of issues that Nelkin (1995) divided into “news reporting,” “news editing,” and “writing decisions.” “News reporting” roughly refers to how individual journalists make reporting decisions and their impact on news accuracy and comprehensiveness. “News editing” refers to how groups of journalists within news organizations initially decide what is news (what is selected to broadcast or publish) and its impact on providing a comprehensive range of science stories. “News writing” refers to writing motifs and narratives (that inevitably are embedded within news stories) and the formation of public impressions about story topics (Logan, Zengjun, and Fraser Wilson 2000b, 6). Within each of these subcategories, some of the issues explored include the following:

#### *1. News Reporting*

- Is science reporting accurate and impartial (Singer 1990)?
- Does news reporting exaggerate the importance of scientific findings (Logan, Zengjun, and Fraser Wilson 2000b; Nelkin 1995)?
- Does news reporting provide qualifications, caveats, and time frames to explain issues, such as the timetable for the public availability of scientific discoveries, procedures, products, or technology (Wilkins 1987, 1989; Wilkins and Patterson 1987)?
- To what extent does news reporting provide a social, economic, historical, cultural, and scientific context (Friedman 1999; Friedman, Gorney, and Egolf 1992; Friedman et al. 1996; Logan, Zengjun, and Fraser Wilson 2000b; Nelkin 1995)?
- To what extent does news reporting reflect a correct use of statistics and mathematics (Cohn 1988; Paulos 1988, 1995)?
- To what extent does news reporting explain the uncertainty that normally underlies scientific findings (Dunwoody 1999; Fumento 1993)?

- To what extent does news reporting help readers distinguish between textbook science (sophisticated, well-understood scientific areas) and frontier science (areas where research findings are preliminary) (Dunwoody 1999; Rowan 1999)?
- Why are science news reports frequently tied to events, such as press releases, speeches, journal article releases, and science convention papers (Boorstin 1961; Nelkin 1995)?
- To what extent does the skew toward reporting events result in news with less historical, economic, and educational context (Boorstin 1961; Logan, Zengjun, and Fraser Wilson 2000b; Nelkin 1995)?
- Is science reporting too uncritical about science (Greenberg 1974; Nelkin 1991; Perlman 1974)?
- To what extent is reporting about female scientists approached as a feature story about a person while reporting on male scientists is focused on their work (Blakeslee 1986)?

## 2. *News Editing (or Topic Selection Processes)*

- To what extent do news editors believe they must publish or broadcast a science or medical news story that is already reported by a competitive news organization (Shoemaker and Reese 1996)?
- To what extent does news selection among a few major news organizations (e.g., the *New York Times*, *Washington Post*, and Associated Press) set the agenda for the science and medical coverage across the United States (Shoemaker and Reese 1996)?
- To what extent does science and medical news selection gravitate toward applied as opposed to basic science topics (Hartz and Chappell 1997; Nelkin 1995)?
- In health reporting, to what extent do news selection tendencies skew toward major diseases (such as heart disease, stroke, and cancer) at the expense of other health care issues (Cohn 1988)?
- To what extent is public attention about serious public health issues, such as AIDS and smoking risks, associated with the press' attention to covering these areas (Sontag 1988; Warner 1989)?
- In science reporting, why does the menu of stories skew toward coverage of "big science" projects, such as the space program and genome research (Nelkin 1995)?
- Why do news organizations infrequently provide mobilizing and coping information or give readers, listeners, and viewers contact information to find out more about the topics within a news story (Wilkins 1987, 1989)?
- Are news selection processes (e.g., internal newsroom decisions about what science and medical topics to cover and avoid) associated with what citizens

believe are important to unimportant public affairs topics (Logan, Fears, and Wilson 1997; Mazur 1981)?

- Do these news selection processes (often called agenda setting) result in how public affairs priorities are established by politicians and how public funds are spent (or are withheld) for scientific and biomedical research (Hartz and Chappell 1997)?

### *3. News Writing*

- To what extent is science news placed in rhetorical contexts, or “frames” (Einsiedel 1992; Logan, Zengjun, and Fraser Wilson 2000a)? For example, how frequently is the underlying topic of medical news stories based on themes that suggest “new hope” and “no hope” for patients (Cohn 1988)? How frequently is environmental reporting framed as a trade-off between protecting nature versus employment opportunities for citizens (Efron 1985; Logan, Fears, and Wilson 1997)?
- Do the impressions left by how news is framed create prevailing impressions that foster public attitudes and judgments regarding science policy (Logan, Zengjun, and Fraser Wilson 2000a; Murray, Schwartz, and Lichter 2001)?
- How can rhetorical and other writing techniques improve the public understanding of science (Rowan 1999)?

### *Some Issues Associated with Scholarship about Channels*

While channels have received less attention than the other areas Westley and MacLean (1957) identified, science communication researchers have explored some channel-derived topics, including the following:

- Are magazines and the print media inherently better suited to provide in-depth reporting about science (Freimuth et al. 1984; Haff 1976)?
- Is television better suited to provide a broader acquaintance with science topics and generate interest in learning more about science topics (Hartz and Chappell 1997)?
- To what extent does visualizing complex scientific process (in television or print) enhance public understanding (Flatow 1997; Ropeik 1997; Rowan 1999)?
- To what extent can the interactive, print, and visual capacities of the Internet (as a mass media channel) be optimized to the Internet’s full potential as a science educational tool (Tremayne and Dunwoody 2001)?
- How do nonmedia channels of science information, such as museums, exhibitions, and the arts, enhance public understanding? To what extent do nonnews

sources of science information supplement public education and the press as sources of science news, information, and socialization (Gregory and Miller 1998; Lewenstein 1992)?

### *Origins of—and the Transition to—the Interactive Science Model*

While the lists above are not comprehensive, Weigold's (2001) literature review underscores how many issues within the field can be categorized within Westley and MacLean's (1957) conceptual headings. Essentially, most science communication research has revolved around (1) the sources of science news; (2) how news is reported, edited, and written; (3) the appropriate media channel to communicate science; and (4) the audience for science. Weigold finds science communication researchers have been innovators in all four ideas, and as noted above, the foundations of mass communication research can be traced to the initial scientific literacy model. In addition, Weigold notes most of the research radiates a concern about exploring how science communication is functional or dysfunctional and often provides suggestions to improve the science communication process.

From a conceptual perspective, a generation of research about sources, messages, channels, and receivers unquestionably has advanced both the classic science communication model and long-standing traditions within mass communication research. Researchers past and present can be proud of and continue the legacy of the scientific literacy tradition.

Yet, as the range of understanding of news sources, news messages, channels, and audiences unfolded throughout the twentieth century, important new questions were raised, such as why there was a lack of progress in elevating scientific literacy in the United States and why significant audiences remained inattentive, apathetic, disinterested, or neglected or rejected science (Dornan 1990; Hartz and Chappell 1997; Hilgartner 1990; Logan 1985; Yankelovich 1982). As Trachtman (1981), Burnham (1987), and later Hartz and Chappell (1997) noted, a generation of sophisticated efforts to work with the news media to boost awareness, interest, and education about science did not expansively elevate the nation's scientific literacy, encourage young persons to pursue careers in science, foster interest in increasing public spending on science and technology research, or create more goodwill toward science. For some citizens, the popularization of science through the news media did not automatically generate interest or increase popular support for tax-supported research. In addition, for some audiences the idealized, transformative experience that Slossen, Heyl, Millikan, and Hale envisioned fell far short of

expectations. As Holton (1993) noted, the growth of “anti-science” perspectives in serious scholarship, public opinion, and popular culture was difficult for scientists to ignore during the last third of the twentieth century.

Following the logic of the prevailing model, some suggested responses to improve the communication of science to the public in the 1980s and 1990s were to (1) redouble efforts to enlist more journalists and scientists to improve public understanding of science along classic traditions, as Hartz and Chappell (1997) maintained; (2) admit unmet expectations and reduce interprofessional efforts to communicate science to lay audiences, as Trachtman (1981) and Burnham (1987) implied; or (3) compromise by targeting news and information toward attentive publics for science, as Prewitt (1982, 1983) suggested. While Weigold (2001) asks if science communication research is currently at conceptual crossroads for these reasons, evidence suggests a quiet shift in the literature probably started in the early 1980s. Regardless of approach, by the early 1980s some scholars realized that fresh solutions were needed to expand the audience for science; generate increased public attention to, interest in, and support for science; and improve citizens’ capacity to make better science policy decisions (Dornan 1990; Hilgartner 1990; Yankelovich 1982). This article takes the position that the leaders who criticized the scientific literacy model’s inertia about twenty years ago helped develop the interactive science tradition as a conceptual alternative to the scientific literacy model. Their initial criticisms of the scientific literacy model centered on the ethics and logic of suggestions to curtail sixty years of interprofessional commitment to the lay public, or target most attentive audiences. As Yankelovich (1982) implied, it seemed conceptually backward to suggest that curbing efforts to improve lay understanding of science could help adults or children better function as citizens. The suggestion to curb public communication efforts also was seen as antithetical to the most foundational ethical value in journalism—the public’s right to know (Lambeth 1992). While ethical theory defends occasional exceptions to informing audiences, such as national security and privacy, the inconvenience caused by declining scientific literacy did not seem to be an ethically based rationale to curb communication (Logan 1985). In addition, the well-meaning suggestions to persevere along established conceptual and practical lines were not seen as innovations (Logan 1999; Yankelovich 1982).

In turn, the frustrations with a lack of progress and contemporary remedies turned into a discussion about science communication’s future and its conceptual foundation. Without immediate solutions, some researchers began to suggest that science communication’s classic conceptual underpinnings might be insufficiently holistic to account for the social dynamics that scientists, journalists, communicators, and citizens faced (Rakow 1989;

Yankelovich 1982). In lieu of traditional options, some scholars began to focus on a new conceptual tradition that could underlie—not replace—the traditional model of science mass communication (Logan 1991; Yankelovich 1982). They hoped a fresh conceptual approach might (1) explain why constructive news efforts sometimes fostered unreceptive to unappreciative audiences, plus (2) provide a fresh start to revise and revive the enthusiasm about bringing science to lay audiences.

Interestingly, a similar crossroads and a conceptual evolution emerged within health communication at the same time. Even after a generation of advancement in understanding audiences, messages, and channels and elaborating social learning theory, Salmon (1989) and Strasburger (1989) noted that well-planned public health campaigns were only modestly successful in changing audience health behaviors. As sophisticated as health communication models became, Salmon argued they were less successful in conceptually explaining a range of negative reactions among targeted audiences. Although researchers reported modest gains in audience interest, awareness, and inclinations to change behavior, by the early 1990s, Salmon argued state-of-the-art campaigns also fostered a simultaneous ill will toward the social institutions that generated campaigns and a perception among some target audiences that health communication efforts were paternalistic. As other researchers observed a decade later, “The *ethos* of intervention campaigns reflects tacit assumptions that are resented and rejected by the very audiences public health officials hope to reach” (Logan and Longo 1999, 83).

If the structure of health communication campaigns was inimical to their success, some health communication scholars reasoned, “there was a pressing need for broader theoretical concepts regarding how health communication occurs” (Logan and Longo 1999, 81). Among health communication researchers in the 1990s, both practical and conceptual needs spawned interest in an alternative model that could explain consumer resistance and offer fresh strategies to improve lay communication efforts. Simultaneously, to some science communication researchers, unenthusiastic or inattentive public responses to popularization efforts spawned a parallel interest in an alternative model that could conceptually explain public apathy and regenerate interest in bringing science to citizens.

Although the motivations were slightly different, within health and science communication research, the development of what Einsiedel and Thorne (1999) described as the interactive science model was a response to practical issues and an underlying conceptual paradox.

By the early 1990s, the fields of health, science, and risk communication converged on a similar interest: is it possible that the prior conceptual emphasis on public information via a news or media transmission model might be

undergirded with a fresh focus? All three disciplines also converged on a similar insight: is it possible to build public communication on a new foundation where the structure of public communication rekindles interest among a broader range of citizens in science?

### *The Interactive Science Tradition*

Einsiedel and Thorne (1999) differentiated the interactive tradition from the scientific literacy tradition by explaining the interactive tradition undergirds a linear, top-down transmission model with a conceptual alternative. Within the interactive tradition, science knowledge is seen as less fixed (or certain) and does not necessarily flow from scientific experts through the news media to citizens. In lieu of pedagogy, the interactive tradition conceives mass communication as more of an informal conversation—a shared and multidirectional experience. The emphasis is less on informing persons than on improving communication among citizens, scientists, politicians, government and corporate officials, and journalists. The efforts to reestablish a dialogue among citizens, scientists, politicians, government and corporate officials, and journalists are seen as a vital first step to rekindling public engagement and interest in science (Yankelovich 1991, 1999).

The interactive tradition's intellectual roots are derived partially from political science (Putnam 1993, 2000), mass communication (Carey 1989; Rosen 1999), and public opinion research (Yankelovich 1991, 1999). Putnam (1993, 2000) noted how, from the 1960s through the 1990s, declines in voting, community volunteer activity, and perceived credibility of social institutions and major professions (among other examples) collectively reflected an erosion in the United States' social capital. The term "social capital" roughly refers to the degree that citizens believe social institutions and the major professions are responsive to public concerns and are dedicated to improving the quality of life for all citizens. "Social capital" additionally means the degree of perceived public trust and goodwill toward social institutions as well as other social indicators, such as the public's confidence that the nation's economic, political, and cultural future will be better than its past. Putnam explained that social capital is less an empirical construct than an informal cultural index that rises and falls over time. Moreover, Putnam argued social capital can be elevated by sincere efforts among social institutions to encourage citizens to participate in civic processes, such as voting, community volunteer work, and discussions about public policy issues.

Similar to Putnam (1993, 2000), Yankelovich (1991) found declines in the perceived credibility of social institutions and the major professions (in-

cluding science, medicine, and journalism) were symptoms of citizen alienation and anomie. Yankelovich (1991) argued secular alienation was a function of declining citizen engagement in public affairs that in turn he partially linked to the top-down, pedagogical process of mass communication. Yankelovich (1991) argued that ironically, by placing emphasis on expert-to-citizen pedagogy, science communicators inadvertently fostered public alienation, inattentiveness, and disinterest and accidentally cultivated ill will toward science as a social institution.

Yankelovich (1991) emphasized that public participation is eclipsed when citizens do not have the media and publicity skills or access to enter public affairs arenas with capacity or influence parallel to organized social institutions (Logan and Longo 1999). Hilgartner and Bosk (1988) added that “expert arenas” (such as the leadership within legislatures, political parties, government, unions, industry, and public interest groups) dominate the debate about science policy as well as risk and health issues. Expert arenas focus public attention around parochial concerns, which “influence legislation and spending [and] helps transform popular skepticism into cynicism about the evidence, motives and credibility of social institutions” (Logan and Longo 1999, 86).

Yankelovich’s (1991) remedy was to focus on the roots of public alienation and encourage social institutions and major professions to establish unprecedented efforts for dialogue with citizens. To Yankelovich, the process of seeking dialogue was more than providing an opportunity for public input into governmental hearings, holding corporate open houses, or providing letters to the editor and discussion groups for Internet readers. A Yankelovich-inspired dialogue is an ongoing, live interaction between scientific experts, policymakers, scientists, lobbyists, and representative citizens regarding the moral, ethical, and affective dimensions of science and medical issues; the linkage of related epidemiological and toxicological issues to public confusion about risk (perception); and a discussion about how power and authority are advanced to make public policy health decisions (Logan and Longo 1999). The purpose is to mediate and inform how biomedicine or science “infuses cultural outlooks, creates options for public consideration, alters the attractiveness of health alternatives, identifies the consequences of public choices, helps raise issues to public attention, and influences social values and valuation processes” (Logan and Longo 1999, 87).

In the history of mass communication research, the conceptual division between the interactive and scientific literacy traditions plus applied strategies, such as public dialogue, were probably first broadly advanced by Carey (1989). To Carey, pedagogically oriented mass communication efforts (such as the classic scientific literacy model) reflected an incomplete conceptual

understanding of the processes of social learning, public education, and fostering responsive citizenship.

Facts aren't enough; people look for a sense of authenticity from information and individuals. The story must "ring true"—reflecting to people a sense of reality that resonates with their experiences and the general belief that they are being squared with. Citizens detect and dislike the inflated language of experts. (Warhover 2000, 50)

While Carey understood that traditional pedagogical models were vital to public education, he maintained citizen involvement in public affairs foundationally depended on social rituals, such as New England town meetings, where citizens could see their interest in public life result in real decisions and social change. As Warhover (2000) explained, "people want a sense of possibility for action before they will get engaged (in social learning and public affairs). They need to believe that progress can be made, that they can participate effectively" (p. 50).

Inspired partially by Carey's (1989) and Yankelovich's (1991) ideas, Rosen (1999) and others (Eksterowicz 2000) encouraged news organizations to foster lay participation in civic processes. Rosen called these pioneer efforts civic or public journalism, which supplements traditional news reporting with specialized coverage that (among other issues) fosters more dialogue between experts and citizens. In the past decade, an array of news organizations throughout the United States has adopted civic or public journalism strategies (Eksterowicz 2000). While the underlying ideas and strategies surrounding civic or public journalism are controversial among journalists (Woo 2000), their existence is seen as a historic, conceptual shift in how journalists perceive their traditional roles and functions (Eksterowicz 2000; Rosen 1999).

Returning to its conceptual impact within science communication, the interactive tradition starts with fundamentally different questions than does the scientific literacy legacy. The scientific literacy tradition conceptually focuses on how accuracy and context are maintained as blocks of knowledge and migrate from scientific experts through media channels to citizens. In the interactive tradition, on the other hand, the foundational questions include the following:

- a. How is learning about science cultivated when the audience is inadvertent, disaffected, alienated, or unmotivated?
- b. How is learning about science fostered when the process of social learning sometimes is not linear and top-down?

- c. How is learning about science fostered when, sometimes, adults and young persons perceive science communication efforts as didactic or paternalistic?
- d. How can science, the news media, and other major social institutions and major professions encourage participation in a democratic society?
- e. How can science, the news media, and other major social institutions and major professions better connect citizens to civic processes?
- f. How is credibility, goodwill, and trust in science (and other social institutions) reestablished once traditional strategies to inform citizens fall short of expectations?

While the conceptual history of the interactive tradition reflects a rich legacy, its range of practical applications and formal evaluation are in their formative stages. Some of the interactive science model's concepts and strategies only recently emerged as important topics within risk communication research (Plough and Krinsky 1987; Powell and Leiss 1997). In health communication, the interactive tradition is reflected by a recent interest in administering town meetings as an intervention to generate audience participation and interest. The town meeting is conceived as an initial step to establish what later becomes a traditional campaign of providing health messages to target audiences (Fawcett et al. 2000; Green and Kreuter 1999; Guttman 2000). One of the first comprehensive, empirical assessments of the community impact of civic journalism found the effort modestly increased citizen involvement in public affairs, modestly elevated interest in learning more about social issues, and boosted the perceived credibility of participating social institutions, including the news media (Lambeth, Meyer, and Thorson 1998).

Nevertheless, the applications and evaluations of the interactive tradition (in science and health communication) are not extensive, especially in comparison with the wide-ranging research that underpins the classic science communication model. In addition, it is premature to assert that the conceptual ideas within the interactive model are grounded by research findings. It is yet to be determined if strategies derived from the interactive tradition (such as social dialogue) have a socially desirable impact (such as elevating social capital).

On the other hand, the interactive model represents an important contribution to the conceptual history of science communication because it provides alternative perspectives and pragmatic strategies that revitalize how public communication might be approached. If nothing else, the interactive science tradition challenged a conceptual inertia that emerged within the field about twenty years ago. The interactive tradition created energy and enthusiasm to expand public involvement in science, refocused professional interests on what practitioners can do to elevate public life, and rekindled the field of

science communication's conceptual momentum. It also provided a fresh sense of direction without undermining the efforts of those who sought to improve science communication in traditional ways.

### *The Two Traditions and Future Opportunities*

While the interactive and scientific literacy traditions are different, they are not mutually exclusive. Although the interactive tradition responds to conceptual binds within the scientific literacy model, the intent of the interactive tradition is to underlie—rather than replace—the traditional view of the science communication process. The interactive tradition does not quarrel with the idea that citizens should be better informed about science, nor does it overlook the important roles scientists, journalists, public information officers, public interest groups, corporations, governmental agencies, nongovernmental agencies, and other professionals play in providing high-quality science information to the public.

To put this another way, the field of science communication is conceptually expanded—not confounded—by the existence of two different conceptual traditions. The interactive science tradition may provide a more comprehensive explanation of how public communication processes occur, but it does not conceptually threaten traditional goals of informing adults and children about science. The interactive tradition is uncritical of the thousands of well-intentioned scientists, journalists, public information officers, and others who try to translate science into useful and understandable narratives for citizens. The interactive tradition simply provides some new issues for science communication practitioners to consider and a range of fresh strategies to attempt to supplement traditional approaches.

In fact, science communication is fortunate to have two conceptual traditions that provide a range of options for researchers and practitioners. While the emphasis above was on the differences between the interactive science and scientific literacy models, a review of their development also reveals that there are commonalities between science communication's subdisciplines and common bases for opportunities and cooperation. Although journalists currently are organized into different peer organizations depending on whether they cover science, health, medicine, environment, technology, nutrition, or agriculture—and the broad field of mass communication of science is spread across three disciplines (health, science, and risk communication)—two identifiable conceptual traditions link all science communicators. The scientific literacy and interactive traditions provide a conceptual basis

for disparate practitioner and scholarly groups to compare professional issues, discuss research findings, evaluate their fields on a cross-disciplinary basis, and learn from each other's work. The commonalities also provide a basis for scientists to discuss the purpose of public communication with journalists and furnish a basis for outreach and dialogue with vital actors in the science communication process, such as public information officials who work with government, corporations, public interest groups, and politicians.

While there are scholars who cross the boundaries of risk and science communication or health and science communication, unfortunately, there is little sustained effort within the three disciplines for researchers to meet, discuss their work, and seek interdisciplinary research opportunities. Similarly, leaders within the National Association of Science Writers, the Society of Environmental Journalists, and the Association of Health Care Journalists rarely collaborate on workshops, common skills, Web sites, and other professional development activities.

While recent conceptual history suggests social and professional learning is rarely linear and progress cannot be rushed or contrived, it is straightforward in suggesting that more interprofessional and multidisciplinary efforts to discuss common issues might accelerate the pace at which science journalism and science communication progress. The overlaps in conceptual traditions in science, risk, and health communication, and between all science communication practitioners, are a foundation for collaboration. The common roots, objectives, challenges, transformations, and questions remain a common point of pride and an underutilized foundation for progress.

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