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CLEAR, COMPELLING, AND CONVINCING SCIENCE COMMUNICATION: DESIGNING AN ONLINE SCIENCE COMMUNICATION LEARNING MODULE FOR GRADUATE STUDENTS IN SCIENCE, TECHNOLOGY, ENGINEERING, AND MEDICAL (STEM) FIELDS

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by

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ABSTRACT

Over the past two decades, online media technology has disrupted the operation of numerous newsgathering and news distribution operations. Science journalism has not been immune from the disruption and, in fact, the rise of online and mobile technologies has deeply impacted the profession, causing layoffs and decreasing job opportunities for science journalists. As the number of professional and independent science journalists and editors has declined and the number of people who are accessing news through often unfiltered channels, such as social media, has increased, there is a growing need for scientists to learn more about science communication in order to more effectively participate in the science news distribution process. Properly trained researchers in the Science, Technology, Engineering, and Mathematics (STEM) fields can help identify scientific advances that the public may be interested in, guide the crafting of messages about health and science and serve as primary sources for science news stories. In this review, I discuss the creation of an online applied science communication module for graduate students in the STEM fields. I will review both the societal and student need for better science communication skills, explain the curriculum development theoretical approaches and design of the module, cover theoretical approaches of science communication, and discuss potential gateways, as well as roadblocks, in developing a course to help scientists communicate their work in clear, compelling, and convincing ways.

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I would like to acknowledge the help of my committee and instructors in the science communication program and my fellow graduate students for their help and support throughout this process.

Chapter 1

Understanding the Societal Need for Clear, Compelling, and Convincing Science Communication

The development of a Science Communication for STEM Students educational module was designed with two overarching goals in mind. First, the module was designed to raise awareness among future scientists about the need to engage in effective science communication. Second, once establishing this awareness, the module was developed to build practical skills in science communication by offering tips and strategies to communicate research in a web-enabled multimedia environment. However, the module, itself, was motivated by an increasing societal need for better science communication, a need driven by technological, cultural, and social trends.

It could be argued that, based on the current media environment, the need for scientists trained in science communication is growing in importance. Like other sectors of traditional journalism, science journalism has faced dramatic economic and technological disruption. Almost 1,800 newspapers in the United States have stopped operation, including more than 60 dailies and 1,700 weeklies (Abernathy, 2018). Many of those newspapers regularly distributed science and health news and some featured dedicated science and health sections. According to the Columbia Journalism Review, in 1989, approximately 95 newspapers featured weekly science sections (Morrison, 2013). In 2005, papers that included a dedicated science section fell to 34. According to the most recent figures in 2012, about 19 newspapers had science sections. In addition, Lucibella (2009) reports that both newspapers and television news desks have reported the layoffs of science reporters and editors.

Newspapers that did not employ dedicated science editorial staff often relied on news services, such as Associated Press (AP), the United Press International (UPI), and Reuters, to supply their publications with health and science news. These services were staffed by trained journalists and freelancers, or stringers, including science writers, editors, and graphic artists. Scholars suggest that the recent economic disruption has also severed local access to science reporting that was once provided by science editorial staff at news services, or wire services. Columnist Marc Wilson reports that the loss of news services, such as AP and UPI, has created a dire situation for the dissemination of professionally curated news and, by extension, professionally created and curated news about scientific advances.

"The news services that support newspapers and broadcast stations have also shrunk. The AP has fewer reporters, bureaus and correspondents. The once-great Washington Post-LA Times News Service was dissolved in 2009. And UPI is little more than an asterisk in journalism history books. The vast stringer networks that AP once nourished have diminished and UPI's once-extensive stringer network is long gone (Wilson, 2014, para. 7, 8)."

Role of Online and Social Media in Science Communication

As the number of trained, professional journalists has fallen off, media consumers are acquiring news and information in through online technologies, including social media. According to Pew Research Center, about 25% of social media users see "a lot" or "some" science posts (Funk et al., 2017). Further, a third (33%) consider social media an important way to access science news. Slightly more than a quarter (26%) follow science accounts on social media.

This growing trend is particularly important for scientists in health, medical, and human development fields. According to the Pew Research Center, the third most popular online activity is searching for health information and about 80 percent of online users say they have searched for health information (Fox, 2011).

The increasing popularity of social media and online sites as sources of science news presents both a threat and an opportunity for scientists seeking to inform the public about scientific discovery and evidence-based policy recommendations and warrants further communication training for scientists as these technologies.

Science Communication in the Age of Science Denialism

The loss of trained science journalists occurs at a precipitous time in the history of health and science communication (Scheufele & Krause, 2019). Most scholars recognize that science is an important source of influence on social and political decision making. However, while science denialism is not new, the number of debates in the public sphere about science-based issues is large and the arguments are increasingly divisive. Diethelm & Mckee (2008) name a few current and recent controversial science issues, including anthropogenic climate change, evolution, the AIDS-HIV connection, and the connection between smoking and lung cancer, to name just a few.

These debates are influenced by the presence and spread of science misinformation, disinformation, and a lack of science information (Scheufele & Krause, 2019). In today's combative science communication climate, Scheufele & Krause (2019) note that today's debates are often propelled by a lack of scientific understanding and that this lack of understanding reveals a deeper understanding of science, including: a lack of both scientific facts and epistemic knowledge about science, the holding of beliefs that are inconsistent with the best available science, inaccurate views, or outright rejection of science consensus, and the acceptance of conspiratorial beliefs (pp. 7662-7663).

The scholars further note that online outlets facilitate the spread of misinformation and disinformation, often broadly labeled as fake news. The ease to which scientific misinformation and disinformation can spread through social media channels, such as Facebook and Twitter, are a source of concern for science communicators and science communication scholars. They note that online environments present several challenges for members of the general public who are trying to both recognize misinformation and gain a clearer understanding of science material.

First, the lack of labeling in online environments make it difficult for the public to separate news from opinions. In the print era, opinion pieces were often found in the editorial and opinion page. It is much more difficult to cordon off news from opinion online. Iannucci & Adair (2017) found that of the 49 organizations analyzed, only 20 of them, or, about 40 percent, offered readers a label for a story on their website at least once in at least one section. Further, of the organizations that labeled articles, 16, or about 80 percent, of them only used labels in the opinion section.

This lack of proper labeling is further compounded by the loss of labels when the story is shared through social media sites. Washington Post editor Marty Baron writes:

> "People do get confused, and it's particularly challenging these days when we're publishing on so many different platforms. Our stuff is going out on Facebook, Apple News, Snapchat, this or that. The context that (an article) had in the print newspaper is completely lost on those other platforms. It's important that we take steps to make sure that people understand what it is, with some sort of label that makes sense (Iannucci, 2017, para. 5)."

Besides a lack of labeling to help people understand the purpose of an article, scholars also suggest that a lack of trained journalists increases the likelihood of misinformation and disinformation spread. S. Shyam Sundar (2019), for example, writes that the lack of "professional gatekeeping," typically undertaken by journalists is a major reason for the ease of acceptance of online misinformation and disinformation.

> "I've been studying the psychology of online news consumption for over two decades, and one striking finding across several experiments is that online news

> readers don’t seem to really care about the importance of journalistic sourcing – what we in academia refer to as ‘professional gatekeeping.’ This laissez-faire attitude, together with the difficulty of discerning online news sources, is at the root of why so many believe fake news. (2019)”

Sundar also writes that in social media environments mostly trained gatekeepers have been largely replaced by mostly untrained gatekeepers. Celebrities and politicians, who may have millions of followers, may not perform the fact checking protocol of a journalist before they share information that they add to their feeds. This increases the possibility of viral disinformation and misinformation online, he adds.

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Chapter 2

Understanding Student Perception of the Role of a Science Communicator

Understanding the need for society to have trained science communicators justifies the development of a science communication education module for STEM students. However, in order to connect future science communicators with that societal need, it is also necessary to understand the perceptions that students have about the role of a science communicator and, indeed, why future scientists might be motivated to undertake the duties of a science communicator in the first place.

The module, then, is guided by the design, development, and instruction of a 3-credit online science writing and science communication course for undergraduate and graduate students at a large Mid-Atlantic Northeastern university. Through personal experience as an instructor for this science writing and science communication course and based on a qualitative analysis of student messages on motivations for attending the class, in particular, as indicated by class interactions and from posts on the course message board, it has emerged that students have a multitude of reasons to communicate science and technology, as well as differing conceptions of a science communicator's role. In other words, they conceptualize the role of a science communicator through their own desire to communicate science and through their perspectives of the science communicator's own motivations, activities, missions, duties, and goals.

Qualitative Analysis Methods

To better understand these perceptions of science communicator roles for the purpose of designing an educational module to match those expectations, an analysis using a grounded theory approach was conducted on student posts to class message boards of three available sections of the online science writing and science communication course. Two of the sections were taught at the 200-level and one was taught at the 400-level. While all three sections were based in the college of communications and delivered through the university's online educational platform, students from other colleges were accepted into the course, including students in the STEM fields. The sections also attracted students from both the undergraduate and graduate levels. The courses included traditional graduate and undergraduate students, as well as nontraditional students, such as returning adults and military students.

In the introduction to the course, students were asked to voluntarily post the reasons why they added the course to an online message board. No course credit was offered for the students' responses or replies. In these three sections, about 49 students posted about 50 total messages and replies to the class message board to introduce themselves to the instructor and fellow classmates. In these posts, students often discussed a variety of motivations for taking the course, including the need for credits and their personal and professional ambitions for learning more science communication. These motivations, in turn, offers glimpses into what the student believed to be the role of a science communicator and their connection to that role.

Grounded Theory

Knowledge construction often requires scholars to engage in various methods and approaches to qualitative analysis, in order to find deeper patterns and connections in data, including messages and text. In the study of this data, a grounded theory approach was important in carrying out the analysis of these student messages.

Grounded theory, which has its origin in Pragmatism and Symbolic Interactionism (Corbin & Strauss, 1990), allows the scholar to approach data collection in a streamlined fashion and arrive at original analysis of that data (Charmaz, 2007). Glaser (2001), in his "all is data" dictum, suggests that this data can be anything that the researcher encounters, including interviews, observations, documents, and messages. In grounded theory, collecting data and building theory are integrated, rather than separate processes (Alsop & Tompsett, 2002). Grounded theory scholars use qualitative coding to analyze data through careful selection and separation of that data. This data, then, is further segmented into groups that help the scholar describe and compare the information. In grounded theory, this process of analysis, generally referred to as coding, is broken down into three stages: open, axial, and selective (Corbin & Strauss, 1990). Grounded theory scholars acknowledge that data collection and analysis are interrelated. As soon as scholars begin to collect data, they begin to analyze that data. Further, the scholar does not work with the actual data, but conceptualizes that data through labels. From these labels, during the axial stage, these statements are further interpreted through themes and connections between themes that emerge during the analysis. For example, in the analysis of the online messages of science communication, themes of what the student hoped to accomplish as a science communicator and how they interpreted the role of a science communicator began to emerge. Finally, in selective coding, one arrives at core categories.

Based on Corbin & Strauss (1990), the criteria used to investigate student motivations and perspectives on science communication should be recognized as guidelines, not rules.

> "First, the criteria should not be regarded as hard and fast evaluative rules, either for researchers or for readers who are judging the publications of others. They are intended as guidelines. New areas of investigation may require that procedures and evaluative criteria be modified to fit the circumstances of the research (p. 20)."

Scholars have used grounded theory to analyze texts in diverse fields and disciplines. Grounded theory has been used by researchers to study experiences with and perceptions of apps (Valvi & West, 2014) and how students used learning management systems (Alsop & Tompsett, 2002). Grounded theory has been used to study relationships and interactions between nurses and clients (McCann & Clark, 2004) and has found general use in ethnographies (Charmaz & Mitchell, 2001).

Informed by grounded theory and an understanding of the above mentioned qualitative approaches, I first surveyed each of the online message boards related to the students' introduction to their classmates to gain a general understanding of the information. From that survey, I began to analyze this data for themes. Then I transferred the messages to a Microsoft Word document to better focus on the students' introductions. I read each message board three times over the period of approximately two hours to gain a more precise understanding of the data and better discern the student motivations and their understanding of the role, or roles, of a science communicator. Following this review, I broadly grouped these conceptualized science communication roles into three categories and labeled them: science communicator as science activist, science communicator as science enthusiast, and science communicator as science journalist. It is important to note that some students mention multiple motivations for becoming a science communicator and multiple conceptions of the role of a science communicator. For example, a student may express an enthusiasm for nature and a passion to preserve natural resources. In those cases, I selected the dominant response for analysis based on how much information the student provided on the role, as well as which role was listed first in their discussion.

Microsoft Word offers the user the ability to highlight text with various colors. In the code book, I chose three colors to highlight statements that suggested the science communicator roles: red for activist, blue for journalist and yellow for enthusiast. Sample statements were also recorded in the code book to guide the analysis. The use of highlights allowed me to, first, differentiate the differing statements and to better represent the patterns of statements. While this was not a quantitative analysis and not a random sample, highlighting the statements also offered me insights into which statements tended to appear more often, as well as a better understanding of which majors and disciplines tended to correspond to which motivations and science communication roles.

Science Communicators as Activists and Advocates

Students in the science communication course often indicate that they signed up to take the course because they are personally interested or invested in specific science topics. These topics broadly included health, science and technology. Others mention that they are concerned about the lack of public awareness, or negative public perception of topics that may harm people, either now or in the future, such as climate change and health conditions. These students view the science communicator as someone who can advocate for those topics to gain greater awareness or acceptance from the broader public.

Many students express frustration at how the media cover science and feel their role as a science communicator is to provide advocacy for more clarity and less sensationalism in science journalism. Students in this category also mention the type of sensationalism that surrounds reporting on psychology, often called pop psychology, in the media. Examples of this include stories on how to make a person fall in love with you and the presence of "click-bait" headlines about mental health. They also feel that the over-sensationalizing in the media could even discredit scientists and psychologists who are not participating in story hype and are conducting legitimate research. Students feel the need to debunk statements that do not match with evidence-based science.

Other students mention a failure of the media to set expectations on science, or give proper context to the scientific process. They suggest that the media over-reacts to new research and makes it sound as though the research will shift paradigms, however, little often changes after the story and the topic is forgotten. They worry that this type of reporting leads to disappointment among young people, who become disillusioned with science because of unfulfilled promises of research. These students believe science communicators should strive to stop this media misrepresentation of science.

On the other hand, some students who fall under the scientists as activist category feel that the media is not doing enough for certain causes. They may feel that the media is ignoring specific topics, or feel threatened by both media and public inaction on certain causes, such as climate change, and believe the role of the science communicator is to raise awareness on specific causes and agitate for policy changes and personal and political action.

Finally, students who have had professional experiences or internships at certain organizations, such as government or nonprofits, often adopt those causes as potential roles for their science communication careers. For example, an internship at a cancer advocacy group may lead the student to want to become a communicator for a cancer research group.

Science Communicator as Journalist

The students who believe the role of a science communicator is to translate technical scientific, medical, and technical information for consumption by and understanding of the general public can be grouped in the science communicator as journalist category. These students often are preparing for careers either as a journalist, who may cover science-related topics, or as a public relations representative who will distribute science-related information to clients or donors. Students in this category may already be practicing communicators in fields that need to discuss or translate science, such as the medical field. These students see a science communicator as a person who can explain complex scientific or medical concepts to the public. Students may also be involved in, or interested in social media projects and see the role of science communicator as someone who can use those online channels to convey complex scientific information to the public and be able to respond to inquiries from the public through those channels.

One ethical charge that students in the science communicator as science journalist category discuss frequently is to not intentionally mislead the public.

Science Communicator as Enthusiast

Some students conceive the role of the science communicator as a way to better express and share their enthusiasm for outdoors and nature. Expressions of fascination of and interest in nature and how nature works tend to dominate these students' opinions on the role of science communicators and their own motivations to learn about science communication. They do not see a science communicator as someone who is restricted to an office or laboratory, but someone who is engaged in nature and is sharing that information so that others can share that appreciation.

Somewhat differing from the activist science communicator, enthusiast want to share, rather than convince, or agitate. Unlike the journalist science communicator, the enthusiast is more likely to mention education of the public as a goal, rather than just translating and passing on information to members of the public.

Enthusiast science communicators often mention a love of the outdoors and an interest in taking part in specific outdoor activities, such as camping and hiking. They enjoy family trips to sites that are scientifically interesting, for example aquariums, zoos, and parks. Students also may see their love of science and nature as a family legacy, something that is passed down to them by a parent or family member. The role of the science communicator, in their view, may be to help other people to realize that science can be both fun and informative, as well as a healthy recreation activity.

Some students connect their vision of what a science communicator does to their love of specific scientific subjects as a child, or as a current hobby. For example, although a student may be embarking on a course of study in business, they may be interested in astronomy and want to communicate about that subject. Some see science communication as a way to pursue their childhood passion qualitatively, especially when they lack certain quantitative skills, or do not have interest in developing those quantitative skills. For example, students lacking skills and interest in math can still write about or create videos about oceanography or veterinary science. This also reveals a possible connection with the science communicator not just as a science enthusiast, but as a science educator.

Implications of Motivations and Roles on Science Communication Education

While students have differing dominant approaches toward their understanding of who science communicators are and what science communicators do, along with how those roles relate to their own aspirations, some commonalities appear. The groups, for the most part, are interested in communicating with a non-technical, non-scientific audience. Many of the students wish to do more than communicate, but persuade. Therefore, the educational module should include lessons in basic journalism to help student communicate science, as well as lessons in persuasive communication to help them become more convincing communicators.

Chapter 3

Science Communication for STEM Graduate Students Educational Module Design

In review, we have fewer trained journalists and more untrained information gatekeepers providing and circulating science news about increasingly more important issues to an audience that may be largely antagonistic toward science and scientists. If so, we can no longer expect that the once passive role of the scientist as a supplier of technical data to journalists who then interprets those results for a mass audience can be an effective model of science communication. By aligning societal need with student understanding and desire, the Science Communication for STEM Graduate Students learning module both encourages future scientists to communicate their work and offer them skills to improve their ability to do so. What follows is an overview of that module.

The target audience for the instruction is graduate students, a group selected for several reasons. First, students at this level have a higher likelihood of choosing a career in the sciences and, therefore, will likely become sources of scientific information, whether they pursue a career in academia or industry. Second, current graduate students tend to be more familiar with social media channels, which increases the likelihood that they will immediately interact as a science communicator. Finally, as demonstrated by the analysis of student motivations for science communication in the previous section, the younger generation of scientists and medical students tend to be concerned with science communications challenges of today, including disseminating information about climate change and vaccinations. For graduate students, the individual benefits of becoming skilled communicators are numerous. Communication skills can help future scientists: improve funding prospects, particularly from funding sources interested in broader impacts; earn respect from their peers, and increase their networks among scientists and policy makers (Kuehne et al., 2014). Therefore, science communications lessons for STEM graduate students presents both a societal and professional benefit.

Course Overview

The module, which is accessed online, is arranged in four sections (see Appendix B) and is designed to be versatile enough that it can be approached as a self-learning exercise or offered in a traditional class environment, depending on the intentions of the instructors. Instructors who choose to integrate it into their class lessons can deliver the module during the semester in a way that best suits their students' learning goals. The course is also configured to fit multiple learning environments and offers the instructor flexible time schedules. For example, the instructor could require the students to complete a section once a week, once a month, or spread all the sections throughout the semester. As added flexibility, the instructor could cover some of the modules in-class, while assigning others to be completed independently.

It should also be noted that this educational module goes beyond just communicating science effectively -- the "clear and compelling" sections -- but also includes lessons that cover theories about persuasive communication and science communication. Students have shown a desire to be advocates for and educators of science-based causes, which requires an understanding of persuasive approaches to communications. Likewise, society is also in need of scientists who can communicate persuasively to the public and lawmakers to guide policy. In sections on science communication theory, the student is exposed to the idea that simply making science clear and interesting may not mean that the general public or policy makers will believe the scientist, or adopt suggestions and policy recommendations. Therefore, scientists also need to be convincing science communicators.

Section One: Welcome to Clear, Compelling, and Convincing Science Communication

In section one of the module, students review why future scientists should be concerned with and engage in science communication. Many of the reasons are outlined in the previous section on the current media climate and the widespread use of social networking technologies. The section draws on Self-Determination Theory (Ryan and Deci, 2000) to explore motivations for communicating science to the public, including intrinsic and extrinsic motivations. In this course, intrinsic motivations include the scientist's own curiosity, enthusiasm, the desire to help the field and society, and the need to advocate for or guide policy. Extrinsic motivations are also covered and include the student's desire for personal brand building, in other words, to enhance his or her career and earn prestige among his or her peers and policymakers.

As will be discussed in an upcoming section on constructivist learning theory, the students are also encouraged to build on their current knowledge about science communication and engage in "hands-on" science communication projects, such as keeping a science communication log, are also introduced here. This strategy is aimed at keeping science communication ideas and tactics in mind as the students engage in daily affairs. First, this allows the student to build on existing knowledge and bring questions back into the science communication class. It should also demonstrate just how pervasive science communication is in everyday settings and, hopefully, further emphasizes the need for science communication skills.

Section Two: Writing About Science — Basic Science Journalism and Storytelling Techniques

The foundation of effective science communications rests on principles and strategies that journalists have used to convey important information to busy, non-expert members of the general public. This section offers practical, applied lessons in journalistic techniques to tell stories, as well as introduces the student to several types of journalistic pieces, such as news releases, news stories, and feature stories, which, even if they are not the writer of these pieces, may offer understanding to the scientist when if they serve as a source for a science reporter. Particular attention is paid to make sure that the student knows that journalistic science writing is different from technical science writing. Journalistic science writing serves a translational function to deliver news from the science community to the public audience.

Section Three: Talking About Science—Media and Outreach for the Scientist

The third section continues to help the student develop applied science communication skills, but in different formats and on diverse platforms. Building on the lessons in section two that showed how to select stories and organize information based on journalistic principles, in section three, students review lessons on how to work with the media and engage in science outreach activities. Because social media is increasingly where the general public receives science news (Su et al., 2017), as well as a source of misinformation and disinformation, the section also includes lessons on using social media to reveal, discuss, and review science on social media platforms. As stories about health findings are often distributed through social media, these platforms are also of interest to those involved in medicine, health, and human development. Social media is a multimedia media platform. Social media content is often visually driven media, for example infographics, pictures and video are often included with posts. Therefore, this section also covers visual and multimedia science communication background and best practices.

Section Four: Convincing Science Communication

As mentioned before, science communicators must also be convincing communicators. Science communication students mentioned earlier, for example, expressed a desire to persuade the public about science-based causes and policies. We can also assume that, as future scientists, graduate STEM students respect rigorous, theoretically driven, and evidence-based approaches to discovery

This section is also included because, in my own experience as a university science writer for nearly a decade, I have noticed that a gap between evidenced-based science communication theory and applied science communication skills. For example, I have rarely encountered discussions on science communication theories, such as the information deficit theory, at conferences and professional development opportunities for science writers and public information officers. Science communication theories offer scientists and science writers powerful tools in communicating research findings and their implications to the broadest audience.

Therefore, the educational module is designed to unite evidence-based science communication theory with applied science communication skills by including this section, which offers basic understanding of the science of science communication. While it is not an in-depth review of these theories, which would be beyond the scope of this module, this section offers overviews of primary science communication theories and models, such as the information deficit theory, low-information rationality, and extended parallel processing model, which will be discussed below. Importantly, the student learns the shortcomings of the information deficit theory in order to move them into a more nuanced model of understanding how science is communicated. In addition to a deeper theoretical understanding of science communication, this section also offers practical take-away lessons that are influenced by these theories.

Information Deficit Theory

Information Deficit Theory, also referred to as the deficit model, knowledge gap model, knowledge deficit model, and deficit theory, describes the way information is transmitted from scientists to laypeople (McDivitt, 2011). As such, the model is based on two theoretical assumptions: that public skepticism is related to a lack of scientific knowledge and that providing enough information to fill that knowledge gap is the best way to lessen that skepticism (Abunyewah et al., 2020; Wynne, 1992). In other words, people are skeptical about science because they do not have enough knowledge. The job of scientists, science communicators, and policymakers, then, is to provide the public with scientific information through various communication and outreach channels. Once that information is provided, the public can make appropriate behavioral changes and advocate for better policy decisions.

Critics of the Information Deficit Theory, particularly critics involved in risk communication, charge that the informed public often does not behave in ways congruent to the risks. For example, residents who lived near a volcano and were aware of the risks, had low levels of preparedness for a possible volcanic eruption (Ballantyne, 2000). Wynne (1992) similarly saw farmers' skepticism about scientists' concern about livestock contamination from the Chernobyl nuclear disaster was prompted not by a lack of knowledge, but from the threat that the warning had on their ways of life, identity, and relationships.

Dan Kahan (2015) refers to the phenomenon that human societies currently know more than ever about how to mitigate potential disasters and yet agree so little on what they collectively know as the "science communication paradox." Rather than a lack of access to scientific information or a lack of scientific knowledge, Kahan see cultural mechanisms behind the science communication paradox. Specifically, he acknowledges identity-defining groups as sources of information for most people. Identity-defining groups include people who share basic outlooks. People are better able to read other members in order to find and vet scientific information.

Alternative Theories of Science Communication

As a theory of science communication, the Information Deficit Theory tends to be descriptive, rather than prescriptive. This simplistic, linear two-step model lacks the ability to guide science and health messaging through the dynamic and complex realm of communication. Borrowing on the persuasive and political communication theories, more recent science communication theories are discussed in the module to give the student some sense of the complexities involved in communicating their science, as well as offer them tools, tips, and tactics to help them bring these theoretical approaches into more practical applications. One of the theories discussed in the module is the low-information rationality theory. This theory shows that acquiring lots of information does not necessarily lead to rational decision-making, as suggested by the Information Deficit Theory. Low-Information Rationality theory, which is typically been used to explore voting behaviors and reactions to policy making, indicates that people are already subjected to massive amounts of information and tend to use heuristics to make decisions (Scheufele, 2013). While the theory is often used to describe and predict voting behaviors, science communication researchers have used the theory to explain public opinion-making on scientific and technological issues, such as stem cells, nanotechnology and climate change (Brewer & Ley, 2011).

The module also introduces the student to Extended Parallel Processing Model, which addresses the complexities in responses to fear-based stimuli. Witte (1992) notes the often contradictory results of research into the effectiveness of fear appeals, such as the anti-drug campaigns that likened the effect of drug use on the brain to a frying egg. Some studies affirm the use of fear appeals (Beck, 1984; Stainback & Rogers, 1983), while others report that fear appeals are ineffective (Kohn et al., 1984). Still other studies show mixed effects of using fear to instill behavior change (Hill & Gardner, 1980). Witte (1992) argues that “threat-by-efficacy interactions are the fundamental determinants of study outcomes" (p. 330). For the student, the overview of this theory in the module is designed to introduce him or her to other factors, such as agency and efficacy, that may play a role in how fear is processed by the message receiver, in this case a receiver of scientific information and news, and how it may affect the acceptance of scientific information.

Curriculum and Science Communication Theories

Finally, the creation of the module, itself, is based on modern approaches to curriculum and course development. Specifically, the organization of the module relies heavily on constructivist theory. Constructivism holds that students make, or construct, their own knowledge (Elliott et al., 2000). Further, the learner constructs meaning through experience (Arends, 1998) and that this meaning is based on an interaction between the learner and his or her experience with previous events and knowledge acquired earlier.

In practice, the theory suggests that while a learner can receive passively, understanding cannot be passed on passively from teacher to student. Instruction should be designed in a way that it connects new knowledge with prior experience. Constructivism also advocates for a socially constructed knowledge, an idea championed by educational reformer John Dewey, who deeply influenced constructivism. Dewey believed that effective education is a result of social interactions and that, ultimately, learning is an act that people do together (Williams, 2017).

In practice, lessons that relate a student's current experience with science communication can help him or her construct new knowledge about science communication strategies and tactics. In this module, also note that lessons covered in earlier modules, such as the organization of a science news story, are later used to build on more complex skills, such as providing information to a journalist during an interview. Scholars often refer to this as "scaffolding," which lends itself to the constructivist approach (Iris Center, n.d.).

Similarly, creating lessons on science communication that are carried out in social situations, such as discussing scientific findings with friends or pitching a science story to a colleague, can provide that social impetus for knowledge creation.

Course Delivery

Clear, Compelling, and Convincing Science Communication for STEM Students is available through the Canvas, an online learning management program. However, the module could be adapted to suit other online learning management programs.

Chapter 4

Limitations and Future Directions for the Course

With fewer trained professional science journalists coupled with more online information distribution networks that provide minimal gatekeeping and fact-checking and an increasing demand for information about advanced scientific, medical, and technical information, training the next generation of scientists to participate in ongoing science communication and outreach is imperative. It is hoped that this module can be used, in a small way, toward that end of both raising awareness about the need for science communication and helping scientists communicate their work in clear, compelling, and convincing ways.

In the case of this module, I acknowledge several limitations exist. First, this module has been designed for graduate students in the STEM fields. The reason that graduate students were chosen for this module, as discussed, is because they are at a stage in their scientific career when they may have more time and desire to explore science communication. Graduate students may be more savvy in the use of online and social media technologies and may be exposed to science communication on these channels. Graduate students, rather than undergraduate students, may be more motivated to learn about science communication because they have taken a significant step -- graduate school -- toward a career in the sciences. Current assessments of the motivations of students to become science communicators and of their understanding of the role of science communicators were conducted on student responses that were overwhelmingly not STEM graduate students. It could be that these assessments, then, are not correct and that will not match up with graduate students in the STEM fields. Further, it could be that other demographics, for example, undergraduate students or current faculty, may make more ideal recipients of this training. In the future, research should be conducted on graduate students in the STEM field specifically to determine their desire for science communication module. This research could drive further modification of this module to suit this group.

Distribution of this training in the university system is uncertain for several reasons. First, adoption of the module will be voluntary, which will limit participation from students and faculty. Secondly, the university leans toward decentralization in science communication and science communication training. For example, there are multiple colleges, institutes, and centers aligned with STEM studies. Multiple groups are responsible for research within those colleges and units. Multiple groups are engaged in communication and science communication, including translational science, research communications, strategic communications, marketing, and public relations teams. In the creation of this module, I personally contacted and met with a number of faculty, research deans, science communicators, and communication leaders in colleges and institutes that are actively producing research in the STEM fields. Therefore, a considerable amount of effort will be needed to distribute this module throughout the university.

In the future, the module should be treated as an organic course. The lessons can be refined to reflect current issues and opportunities in science communication. It should remain open to new theoretical advances and interpretations. The module can also be built out to serve as a platform for multimedia content, a growing area of opportunity for applied science communication. For example, the module might also serve as a place where science communication graduate students can contribute their own content, for example, a video of a student's evidence-based science communication tips, infographics from a recent conference paper, a student science communication podcast, and other forms of multimedia content.

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Appendix

Educational Module

Welcome to Science Communication for Scientists!

SPECIAL FEATURES

The New York Times.

SPECIAL FEATURES

EINSTEIN EXPLAINS HIS NEW DISCOVERIES

In a Simplified Discussion of "Field Theories, Old and New," the Eminent Scientist Shows the Meaning Of His Latest Contribution for Gravitation, Electro-Magnetism and Our Ideas of Time and Space

We wanted to say hello and thank you for signing up for this introduction to science communication.

Whether you pick up a newspaper, check your Twitter feed, or check out a news website, it's increasingly clear just how important science communication is. As each day seems to bring news of a major scientific or technological advance, rumors of a simmering controversy about climate change, or word of a medical breakthrough, the ability to write and talk about health, science and technology in clear, compelling and persuasive ways is absolutely vital .

And as a scientist, we believe you will play a crucial role in this effort to make sure the public is better informed about the latest scientific findings and how these discoveries might change their lives.

So.

No pressure.

But don't get too worried. It's not the intent of this course to teach you how to be a science communicator. It's designed to make you realize that you already ARE a science communicator. As a scientist, you already discuss science to your colleagues in your field, to scientists in other fields, and probably to your non-scientist friends and family. What we will try to do is to become more conscious of HOW we communicate matches with WHOM we are communicating.

Why Should Scientists Care About Science Communication?

I wanted to start this section with a solemn recitation about climate change and vaccination opposition to prove to you that you need to care about science communication. I was even going to add exclamation points and put it in all-caps.

Like, "YOU SHOULD CARE ABOUT SCIENCE COMMUNICATION BECAUSE THE EARTH IS ON FIRE!"

But, I've learned -- as you will, too, hopefully -- that sometimes using the emotion of fear to prompt changes in attitudes and behaviors can sometimes backfire. So, I'm going to heed my own advice and tell you about ALL the ways effective science communication can be good for your career, your institution, and our community.

So, let's look at the National Academy of Sciences' five goals of communicating science.

- Simply to share the findings and excitement of science.
- To increase appreciation for science as a useful way of understanding and navigating the modern world.
- To increase knowledge and understanding of the science related to a specific issue.
- To influence people's opinions, behavior, and policy preferences.
- To engage with diverse groups, so that their perspectives about science related to important social issues can be considered in seeking solutions to societal problems.

Let me add just a few others, some might not be as lofty as the above, but you should still consider these ideas.

Communication is part of the scientific process. Because science has become so international and so interdisciplinary, you're not likely to reach all the potential allies -- and equally important critics -- if you stop at publishing in a scientific journal. Communicating your findings in other media and on other platforms increases your ability to make those connections.

Get a job! Do you know how potential employers might find out about you, or your work? Do you know how they'll research you before the interview? They'll use Google or they'll check out your social media presence.

Get funded! Do you know how potential funders -- government, NGO, industry, etc. -- might discover you or your work? You guessed it -- they might stumble on your name and your work on the web, or through social media.

What Do I Need to Know Before I Begin?

Before you start this module, here are a couple ideas to help guide you through this course and point you toward further lessons in science communication. (We'll provide some resources for that at the end of the module.)

Here are a few questions that can help clarify your goals and prepare yourself for the course.

1. What are your goals?
Think about what type of science communicator you want to be. Do you want to advise government agencies or NGOs? Are you interested in communicating with the broad public? Would you like to appear in the media? Maybe you want to be a science journalist? Or even work for a sci-tech organization and know that interpersonal and communication skills are important for success in that position. Answering these questions can help you focus throughout the module.

2. What type of media are you comfortable with?
In this module, we will review many of the most popular media, including print, online and visual. Try to brush up on skills you already have when you review those lessons, but remain open-minded to working on skills you might not be as comfortable with.

3. How familiar are you with science news and media?
This may sound obvious, but, STEM grad students are often too busy with research papers to read newspapers or online science news. Take some time to read science stories in the news today and see what is done well -- and what's done not-so-well. Capture those ideas and questions and bring them to this class.

Exercise 1-1: Homework Already? Keeping a SciComm Log

Publish | **Edit** | ⋮

For this assignment period, keep a log of science stories you see in the media. It doesn't have to be elaborate -- but it can be. Jot down the media -- television, online, social media, word-of-mouth, etc. -- and what the story was about.

Be as broad as possible and try to step outside of your field of expertise. Listen to the words, "according to a study." Or "A team of researchers said..." Or if someone asks, "Did you hear about the study that said..."

Points 0

Submitting Nothing

Due	For	Available from	Until
-	Everyone	-	-

+ **Rubric**

Exercise 1-2: What? More Homework? Translating Science

Publish Edit ⋮

Here are a few real-world exercises you can try -- now, or later -- to start building those science communication skills.

- Find a research study online, you can use Google Scholar, for instance. Read the study to get a sense of what it's about. Now, find a partner in class and explain that story to them. Try to explain the science in terms you both would understand.

- Think about the coolest science fact or process that you have discovered so far in your STEM class this semester. Now, call a relative or a friend and explain in terms that they would understand the background, the science fact, and its implication. After you're done with the explanation, ask them if they understood what you're talking about. Ask them if they have any questions.

FOR THE BOLD

- Go to a restaurant, bar, coffee shop, or some other public place and find a friendly face. Tell them you are taking part in a class assignment and want to give them a science lesson. As above, think about the coolest science fact or process that you have discovered so far in your class this semester. Explain in terms that they would understand the background, the science fact, and its implication.

Congratulations. You're a science communicator!

Points 0
Submitting Nothing

Due	For	Available from	Until
-	Everyone	-	-

+ Rubric

Introduction: Clear and Compelling Science Communication

"Nothing in science has any value to society if it is not communicated, and scientists are beginning to learn their social obligations."

-- Anne Roe, The Making of a Scientist (1953)

If scientists were "beginning to learn their social obligations" to communicate science back in 1953, just think how those lessons have both increased in importance and grown in complexity over the past few decades. And think about just some of the wicked communication problems that have grown around scientific issues in the past few decades, such as climate change, gene therapy, GMOs, vaccinations, etc.

As scientific endeavors have become more complex, the ethical considerations have become even more nuanced. Science and technology have also become more integrated in everyone's life, often in subtle ways. And, science communication has moved from beyond traditional types of media -- newspapers, television, and radio -- of the mid-20th century to an always on, always connected online and social media of the current century.

As a scientist facing this challenging environment, this module is designed to offer you some tools to communicate science in **clear** and **compelling** ways.

Compelling. First, we'll learn how to connect with the general audience, people who do not have a scientific or highly technical background. We'll learn to identify aspects of your research that will interest that audience. By focusing on that information, we will make our science more interesting to a wider range of people.

Clear. We will also cover tips to make our science stories clear, or, in other words, make it more accessible. That means we need to drop the jargon, use common words and make sure we are explaining terms and processes that the average person might not understand. We will also learn how to avoid over-promising the results of our studies, something that's especially necessary for those of you considering careers in the health science field.

Fortunately, an entire profession has been established, a profession with a long history of communicating difficult concepts to the general populace. We call these folks, *journalists*, or *reporters*. Over the past few centuries, or so, journalists have gathered time-tested principles to help us create stories that are both clear and compelling. When those principles are focused on telling people about science, we might hear this called *science journalism*.

Science Journalism: What Makes Science Newsworthy?

Journalism is writing for readers, particularly busy readers. When we use the principles of journalism to guide the telling of science stories, we avoid embellishments, but strive to make sure our stories remain clear, compelling and powerful. Our goal is to inform readers about scientific developments in the clearest, most concise language possible.

It sounds pretty easy, but why, then, do many people, particularly scientists, say they find it so difficult?

Most people were trained to approach writing as an art or as an academic exercise. In the hands of a brilliant writer, indeed, language can be beautiful and entertaining. Informing the audience can be a secondary concern in these pieces, however.

Academic writing is weighted toward precision but, it is typically written for specialists, not for the general audience. Studies and stories published in the academic press tend to be filled with jargon and insider's terms that only scientists and usually scientists in a particular field can understand. Finally, academic writing tends to make a case, starting with theories and prior literature, then building toward an explanation of the methods, and, lastly, coming to conclusions. That doesn't fit the reading attention of a busy reader.

Science journalism -- what we want to emphasize in this module -- aims to find a spot in the middle. A good science news story will be disciplined enough to cover the intricacies of the discovery, but also be able to explain it clearly enough for a layperson with a limited science background to grasp what is important. A science article for the general audience is designed to deliver the most important and relevant information first, then explain the context and methods of the study.

Although there are certainly news articles that are eloquent and entertaining, journalists know that their first job is to inform first, then entertain or amuse.

Newsworthiness

As science journalists, our first step is to know what is newsworthy. We need to ask ourselves questions, like:

- What interests a reader?
- What makes a reader stop what he or she is doing and dive deeply into an article?
- What makes a reader stop scanning through their Twitter feed and jump to a story?

Exercise 2-1: Now That's Interesting!

Publish | Edit | ⋮

So, let's see if we can break down news elements of a science story.

In another window or tab, navigate to one of the following pages:

https://www.sciencemag.org/news (https://www.sciencemag.org/news)

or

https://www.nytimes.com/section/science (https://www.nytimes.com/section/science)

Find a few stories and read them. Then, see if you can identify news elements in those stories. In other words, what makes these science stories, science NEWS stories. Are they especially timely? Is there an element of notoriety -- famous scientists, famous conditions, etc.? Is there conflict involved?

Most stories contain more than one news elements. So list as many as you can.

Points 0

Submitting Nothing

Due	For	Available from	Until
-	Everyone	-	-

+ Rubric

Building a Science Story

As a scientist, you may never need to write a science new story, or a science news release, or produce a video news release, but there is a good chance that you might be the subject of one of those pieces. Therefore, it's probably a good idea to know the basic structure of a science news story, so, if you are ever interviewed you'll have a good idea of what information the journalist or information officer needs -- and, equally important, what information they don't need.

Just as a building has a blueprint that tells the builder where all the pieces go, a science news story tends to follow a specific format, or construction. It tells the writer or producer where to put all of the right blocks of information so the reader can easily absorb the information.

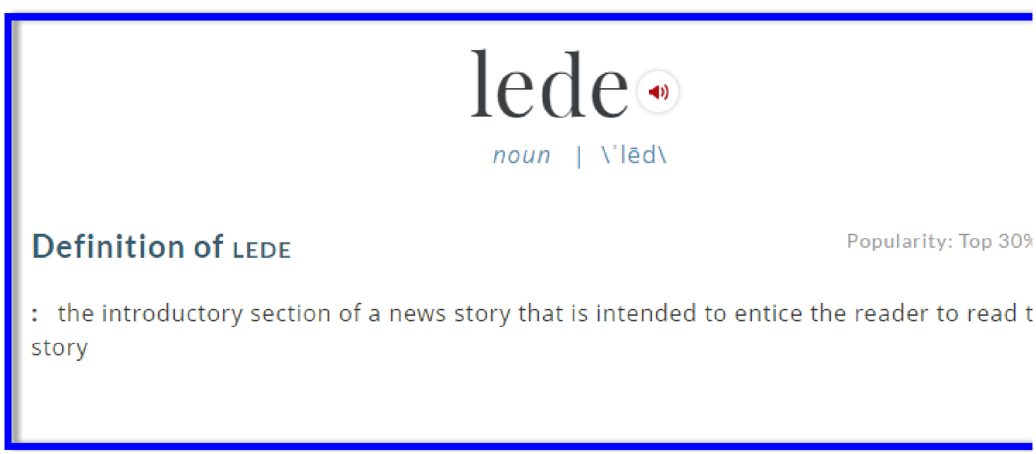
In crafting a science story, the foundation block of that story is called *the lead, or the lede*.

The blueprint for the rest of the news story typically arranges information in a descending order of importance (most important to least important), which means info that the readers really need to know is placed at the beginning of the story and less important findings and implications are added later. You may have heard of this, but, if not, this format is called the *inverted pyramid.*

Now. Let's talk about that lead sentence.

The Lead

Once you know what makes a story interesting, you need to know how to present that information for readers. Journalists spend a lot of time obsessing over something called **the lead -- or lede.**



Credit: Merriam-Webster Dictionary

How To Write a Science News Lead

Most writers will tell you when they spend most of their time thinking about their leads, writing their leads and then rewriting their leads. There are a few reasons for that. While there's no perfect way to write a lead, there are a lot of bad ways to write a lead. So, lead writing involves some experimentation.

The other reason writers obsess on leads is that, like a key piece of a jigsaw puzzle, the rest of the story falls in line once you have a good lead in place.

Here are a few scenarios that show how leads can help you as a scientist.

- If you're working on your own news release or blog post, the lead is critical for a clear, compelling and convincing story.
- If a journalist is interviewing you, knowing this information can help you deliver the right information and set the tone, which can help a journalist craft his or her science story.
- If you want to attract a funder, or corporate sponsor and would like to show the broad impact of your work, a lead can serve almost as an "elevator" pitch for your research.

Set the Tone | Use Your Senses | Avoid Passive Voice | Use Strong Verbs | Write and Re-Write | Read It Out Loud | Talk To A Friend | Avoid "I" leads, "You" leads and Question leads.

Your lead can set a tone for the rest of the story. Weird. Desperate. Serious. Important. Light. Funny. Quirky.

Research has a palette of tones. Some research is earth-shattering and reality-bending in its importance. Some findings are contrarian. Other studies are funny. Your research story should convey the tone of the research.

One way to get your reader into the tone -- or the mood -- of the piece is to match the tone of your lead to the rest of the story. Be careful, though, a disconnect between the lead and the story can confuse -- or even anger -- your reader. You don't, for example, want a zany lead for an article about an epidemic sweeping through a country.

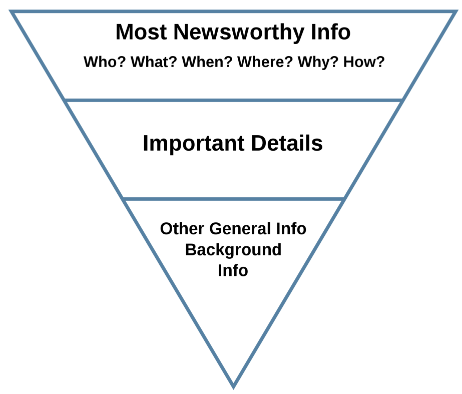
Don't make the mistake of thinking that the lead -- while important -- is not solely important. The rest of the information you need for a complete science story is important, too. And that's why we'll turn to, "the rest of the story."

And, Now, the Rest of the Story

Journalists are busy writers who write for busy readers. One of the tools they use to write effectively and quickly is writing forms, or templates. Journalists know pretty much where the information goes, eliminating a lot of the guess work -- and the time spent on that guess work.

The Inverted Pyramid

Journalists often rely on a writing template called the inverted pyramid. Simply stated, the most important information comes at the top of the story and the rest of the details are added in descending order of importance.



The inverted pyramid is a win-win for journalists. Using their own understanding and intuition of news values, the reporter can efficiently put together a news article in a short amount of time. For readers, the template gives them the most important information, as soon as possible.

Science writers also want to bring in **paraphrases** -- a summation of what a source says -- and **direct quotes** -- exactly what the source says -- to add personality and authority to the story. Quotes and paraphrases also allow the science writer to explain complex scientific material in a conversational and concise way.

Take Away! Don’t be afraid to use quotes and paraphrases throughout your story!

Hourglass Style for Science Writing

Not every journalist uses the inverted pyramid, but most use a variation of that idea. A science journalist, for example, may use an inverted pyramid, but may also use **Modified inverted pyramid or hour-glass** form that starts with an inverted-pyramid to tell readers about the most important finding, but then adds information on the research methodology, or how the research was carried out in a more step-by-step based fashion.

This is helpful to illustrate the implications and benefits of the findings, but also cover the details of the study or experiment in a step-by-step fashion.

Editorials and Op/Eds

Scientists are often called on to provide guidance to the public and policy makers. Often this guidance is requested. But, more often than not, scientists are motivated to share vital scientific information out of a desire to help others, a feeling of responsibility to inform society, or commitment to engage with the public .

One way to share your wealth of scientific knowledge is through editorials, opinion pieces, or op-eds.* In this section, we will pass on some tips, in case you are called on to write an op-ed, or would like to submit an opinion piece. Although op-eds still exist at major media sites -- and they're still widely read and well-respected -- you can use the following information from the **American Association for the Advancement of Science (https://www.aaas.org/programs/center-public-engagement-science-and-technology/writing-op-ed)** (AAAS) to help you craft science-based opinion pieces no matter where they appear -- online, on video, etc.:

- **Consider the goal.** Consider why an op-ed is warranted. Focus on a relevant topic and offer a distinct perspective. When possible, tie the story to an event or discussion currently in the news. Often opinion editors select op-eds that comment on a current issue or offer opinions that are missing from the public conversation. Don't become frustrated if an op-ed submission does not get published. Newspapers typically receive far more op-ed submissions than they can print.
- **Make one major point.** Opinion editors seek clear, concise opinions on a topic — not discussions of two or more perspectives on an issue. Clearly state one major point with a strong perspective.
- **Abide by the word limit.** Call the newspaper to ask about any guidelines for op-eds, including the word limit. The word limit may vary greatly from one newspaper to another, but a typical range is 250 to 750 words. Stay within the limit to increase your chances of getting published.
- **Include contact information.** Always include an address and a phone number with a submission. Include your title and affiliation too, if appropriate. Be responsive if the op-ed is selected for publication or if an editor has questions.
- **Respond promptly.** Timeliness is key. Always respond to inquiries in a timely manner to improve the odds of being published.
- **Submit to local newspapers.** Don't rule out local papers! In the age of the internet, people all over the world, including members of Congress and other policymakers, can access local papers. Smaller newspapers do not have as many op-ed submissions as larger, national newspapers, which increases the chances of publication.

Andrew Rosenthal, editorial page editor, offers his advice for writing an op-ed piece. He recommends you know what you want to say -- and get your point across quickly.

Below is a link to a video where you can hear more from Andrew.

Tips and Tricks

Now we have some ideas about the form science writing can take -- news releases, editorials, etc. -- here are some subtle ways you can make those pieces more interesting and more relevant to the general audience:

Simple -- This bears repeating, but choose simple words and avoid elaborate sentence construction. Short is better than long, generally speaking.

Examples -- When possible, use an example and walk your reader through that example.

Analogies -- In an analogy, we use a simple word or idea to make a comparison. (The mitochondria is like a power plant for the cell. A tectonic plate are like those airport moving walkways, etc.) When used judiciously, analogies can be like a magic wand converting complex scientific principles and processes into understanding and knowledge. See what I did there?

Do The Math -- Relate statistics into real-life lessons. For example, convert a dollar figure into an item in a person's daily budget. How many cups of coffee? How many weeks of groceries for the average person? Convert big numbers, too. How many times around the earth would that plastic stretch? Be creative -- and accurate.

Simple Explanations -- We will have to introduce jargon and unfamiliar words at times. Make sure you take the time to explain those terms. You can even -- **dash off the explanation** -- right after the term.

Embrace Diversity, Find Commonalities -- It's easy to say, "know your audience." That's an important part of this. But, we write for such DIVERSE audiences. They come from different races, cultures and creeds. They have different backgrounds and experiences. Get to know who you're writing to and what's important to them. You'll find we may all be different, but we have a lot in common. Focus on those commonalities when you're trying to explain science.

Exercise 2-2: What's Your Type?

Publish Edit ⋮

So, now you know that there are different types of science stories out there.

Can you go through a newspaper, an online news site and identify:

An evidence-based news story?

An editorial or opinion piece written by a scientist?

A feature story about a science topic?

Points 0
Submitting Nothing

Due	For	Available from	Until
-	Everyone	-	-

+ Rubric

Introduction

The skills of journalism, obviously, are not limited to written science communication pieces. You can apply these lessons to virtually every format where you are asked to convey scientific advances, questions, and findings in clear, compelling, and convincing ways.

In this section, we will review some of those formats.

In this section, you can learn how to:

- Work with members of the media and serve as an interview subject.
- Conduct constructive conversations on social media about scientific topics.
- Talk about science in public forums, seminars and webinars.

To start, head to the next section!

Working With the Media

Scientists view the media through a few different lenses.

They are heroes who can expand the reach of science so that the public and policymakers can make better, more informed decisions.

They are nincompoops who constantly get the science wrong.

They are shady content peddlers who are always looking to hype a story, or condemn a scientist.

They are indifferent jerks who need to be wooed so a hard-working researcher can get his or her story in the public (and maybe into a tenure package).

The truth is, the media are all of those things. And none of those things. And a little in between those things. In other words, each journalist is different, just as each scientist is a little different. Rather than looking at the media as one blank canvas of hopes -- and maybe fears -- you should look at it as another set of relationships, just like your collaborators in your lab, or your colleagues at other research institutions, or your students in the classroom. Relationships must be built and maintained. That means each time you interact with the media, you should work to establish trust and credibility. Here are some typical interactions.

The Interview

Usually, the scientist-journalist relationship starts with an interview. Interviews can be conducted over email interviews, or on the telephone, but, it's the face-to-face interviews that scientists often struggle with.

But, they don't have to be. In fact, when you get the hang of it, face-to-face interactions can promote more powerful and more persuasive communication. And because you already worked through the module on science storytelling, you already have a head start. Yo know have a better idea of what the reporter wants and some sense of what he or she will do with the information you pass on.

Now, let's review some more specific tips on how to handle interviews now.

Tips On Working With The Media

Believe it or not, not every journalist is out to make scientists look bad and demean their work. In fact, the majority of interviews are constructive, amiable, and even, dare I say, fun events. And, bonus, they can help spread awareness about your work and science in general.

Here are some quick tips on talking to a reporter.

Understand the Ask -- Make sure you understand exactly what the reporter wants. Is this a two-sentence soundbite? An extensive interview? Is this for a feature story? A television news clip? Are there specific pieces of research that interest them? Be sure to ask questions, if they didn't provide this information up front.

Understand the Audience -- Who, ultimately, is the reporter writing for or broadcasting to? Try to gain some insight into the audience's expertise level and comfort with the subject matter. Try to learn what the audience really wants to know. This will help you customize, as best as possible, your message to that crowd.

Knowing all of this info will help with the following steps in the interview process (Liang et al., 2014, (https://journals.sagepub.com/doi/pdf/10.1177/1077699014550092) McCurry-Schmidt & Ona, 2016 (https://www.scripps.edu/newsandviews/e_20141013/mediatips.html)) (https://journals.sagepub.com/doi/pdf/10.1177/1077699014550092) .

Be Prepared -- Review and know whatever pieces of information may be helpful to the reporter. And this is exactly what you want to do... help.

...But Don't Be Overprepared -- Scientists who over-prepare may come off as scripted and dull. They may go too deep into the weeds to be of any use to a reporter. Know enough to be confident and be confident enough to be flexible during an interview.

Be Succinct -- Whether it's written, audio, or video, reporters don't have unlimited space. Make sure your comments are to the point. Use the least number of words possible and make those the shortest, least jargony words possible.

It's OK to Say 'I Don't Know" -- Don't speculate. If you don't know, say you don't know. Or say you don't want to speculate.

Use Bridge Words -- Sometimes, your interview may go off topic. It might be your fault. But it might be the reporter's fault. That's OK. Just use some "bridge" phrases to get you back on track. The include: "I don't know about that; what I do know is…" "What's important to remember is…" "Let me put that in perspective…" "I think what you are really asking is…" "What your viewers/listeners need to know is…"

Social Media

Ils doivent envisager qu'une grande responsabilité est la suite inséparable d'un grand pouvoir ("They [the Representatives] must contemplate that a great responsibility is the inseparable result of a great power") -- *Plan de travail, de surveillance et de correspondance, proposé par le Comité de Salut Public aux Représentants du Peuple, députés prés des Armées de la République* of the French National Convention

"With great power there must also come great responsibility" -- Spiderman

Well, you get the picture. Social media has done wonders for scientists and science communications. Before social media, scientists relied on science journalists to find their studies, translate their studies for the general audience, and distribute this information through their medium, for example, print, radio, or television.

With social media, anyone can distribute whatever they want whenever they want.

That presents a dilemma for science communicators. On the good side, we now have the power to promote our research without restrictions. However, on the bad side, we now have the power to promote our research without restrictions.

The ultimate lesson for us in using social media to promote science is, as Spiderman, or representatives of the French National Convention would tell us, use this power, but use it responsibly. Remember that all the former guidelines that we discussed in crafting science communication apply. We want our science messages to be clear, compelling and convincing.

Here are five basic guidelines to consider:

Simple -- If you're hoping to connect with a general audience through social media, all the rules we discussed in previous sections still apply. Posts and tweets should be as simple and as clear as possible. Simple words. Simple sentences. Clear thoughts.

Visual -- Using visual elements, such as videos, infographics and pictures, can help you in two ways. First, they attract attention. Second, they can help better illustrate your science.

Know Your Media -- Each social media "channel" is better at promoting certain types of content. Photos and infographics do well on Instagram. Longer posts and videos can do well on Facebook. Quick updates are suited for Twitter. For best results, consider carefully the content you're creating and how you would like it consumed. Then, match that content with the proper channel.

Viral Is Good, Viral Is Bad -- Really think about every item you post. Is it fair? Is it responsible? Are you avoiding hype? If the post goes viral, will you regret it?

Visual Science Communication

You've probably heard "a picture is worth a thousand words." Journalism has a similar bit of advice: "show don't tell."

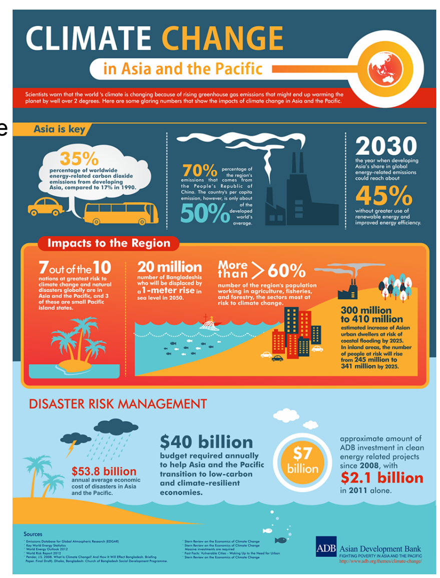
In science communication, visually representing your health and science data can both grab the public's attention and help them better understand scientific findings. Art may also make your work more **persuasive**. This fits our goal of making science **clear**, **compelling and convincing** for as many people as possible.

According to visual science communication research, here are some reasons to visually represent your work and things to consider when you create that content.

Infographics -- Researchers found that using visual content -- especially infographics, which combine visual effects and text -- is an important part of illustrating messages about environmental issues (Lazard & Atkinson, 2014).

It can make the the message more persuasive, they add, concluding, "When environmental messages incorporate visual components in the form of infographics, they are more engaging than messages that rely just on text or just on illustration."

Here's an example of a science-based infographic:



Tips for Powerful Visual Science Communcation

According to Shanks et al. (2017) infographics should "use evidence- and practice-based data, compelling statistics, easy-to-read fonts, complimentary color schemes, simple charts, bold graphs, and other graphics to disseminate information in quick and easily digestible format."

Use an Action-Oriented Headline -- If you want to persuade people to take action, then point them in that direction. Wansink & Robbins (2016) report that action-oriented headlines can make your infographic memorable and compelling. The scholars use the headline "Eat 3 Fruits a Day," as an example of an action-oriented headline. The time spent on crafting a quick (just a few words) and action-oriented (urging the reader to adopt a behavior) headline is worth the effort, according to the researchers.

Public Talks and Seminars

As a scientist, you may be asked to talk to the public about your research. These can be live seminars -- or even online talks and demonstrations.

You might even be called on to do a TED Talk, which are probably one of the more famous examples of how scientists can connect their research with a general audience.

The cool thing is, most of the lessons that you learned thus far in this module pretty much apply to science presentations. People want clear, concise, compelling information. They also want to know how the science connects with their own worlds and lives.

Here are a few tips from Marilynn Larkin from her article, **How to Give a Dynamic Scientific Presentation** **(https://www.elsevier.com/connect/how-to-give-a-dynamic-scientific-presentation)**. She lists five specific pointers for developing content for your presentation:

1. Know your audience. Gear your presentation to the knowledge level and needs of the audience members. Are they colleagues? Researchers in a related field? Consumers who want to understand the value of your work for the clinic (for example, stem cell research that could open up a new avenue to treat a neurological disease)?

2. Tell audience members up front why they should care and what's in it for them. What problem will your work help solve? Is it a diagnostic test strategy that reduces false positives? A new technology that will help them to do their own work faster, better and less expensively? Will it help them get a new job or bring new skills to their present job?

3. Convey your excitement. Tell a brief anecdote or describe the "aha" moment that convinced you to get involved in your field of expertise. For example, **Dr. Marius Stan** **(http://www.anl.gov/contributors/marius-stan)**, a physicist and chemist known to the wider world as the carwash owner on ***Breaking Bad*** ***(http://www.amctv.com/shows/breaking-bad)***, explained that **mathematics has always been his passion** **(https://www.elsevier.com/connect/dr-marius-stan-breaking-stereotypes-by-breaking-bad)**, and the "explosion" of computer hardware and software early in his career drove his interest to computational science, which involves the use of mathematical models to solve scientific problems. Personalizing makes your work come alive and helps audience members relate to it on an emotional level.

4. Tell your story. A presentation is *your* story. It needs a beginning, a middle and an end. For example, you could begin with the problem you set out to solve. What did you discover by serendipity? What gap did you think your work could fill? For the middle, you could describe what you did, succinctly and logically, and ideally building to your most recent results. And the end could focus on where you are today and where you hope to go.

Exercise 3-1: Science Reporter on Duty

Publish **Edit** ⋮

Here are some fun -- well, hopefully fun -- role playing exercises you can build your science communication savvy.

Play Reporter -- Find a professor, colleague, fellow student, whoever... and role play being a reporter. Ask your colleagues to play reporter and interview you about your work. Then, switch! You interview them about their work.

Shadow a Reporter -- Ask a reporter, or a university science information officer to let you go along on an interview with them. Go on a couple! Most won't mind, they might actually enjoy it -- and, who knows, they might even let you ask a couple questions.

Live Tweet -- Go to a science conference and "live tweet" the proceedings. After you're done, look at some of the other tweets from the same conference.

Volunteer -- If you're part of a lab group, or research team, ask to serve as the social media lead, or media specialist or them. Most have a social media presence and lots interface with the media.

Points 0
Submitting Nothing

Due	For	Available from	Until
-	Everyone	-	-

+ **Rubric**

Exercise 3-2: Visualizing Science

Publish | Edit | ⋮

Are you working on a project, or can you find a research study, or science story in media, and better visualize that data?

Think about using graphics and text to make the information clearer and more understandable for a person without a science or technological background.

Or, can you pair a visually interesting photograph or piece of artwork with one of the science stories you selected to draw interest from the general public?

Here are some tips on visualizing science from our colleagues at **CLIPS (https://www.clips.edu.au/infographics/)**.

You can draw some inspiration from **Visually (https://visual.ly/science-infographics)** and **Pinterest (https://www.pinterest.com/aswimm/science-infographics/)**.

Points 0
Submitting Nothing

Due	For	Available from	Until
-	Everyone	-	-

+ Rubric

Introduction: Science Communication's Last Mile

Put yourself in the place of many scientists and science communicators:

You have taken care to consider your audience. You've crafted compelling science pieces, making sure that they have used language that most people understand. Then you deliver the message in media where the audience can easily access it.

And... nothing. In fact, some of your audience refuse to believe you! They might even be a little mad at you. Some might even smell a conspiracy -- and think you're part of it!

What happened?

The science was clear, concise, and compelling.

If you were in the place of that scientist, what would be your first reaction? You might get frustrated. YOU might be the one who gets angry and smell a conspiracy. And, you might even lash back at these naysayers.

Does this sounds familiar?

This is where the **Science of Science Communication** comes in. While we might take great care to craft a message, we might need more understanding to craft clear, compelling and **CONVINCING** messages.

In this module, we'll review:

- Some basic and important theories of **science communication**
- How these theories shape our understanding of science communication
- How new ways of understanding theories of science communication can help us respond to critics and denialism
- Science communication takeaways

Theory I: Information Deficit Theory

As scientists, you know that all great fields of discovery need great theories to provide a firm foundation. Science communication is no different. In fact, there's a growing field of scholars who are exploring ways that scientists can be more effective in communicating complex and technical information to the general public.

Let's just call this "**the science of science communication.**"

We'll start with the most basic theory of science communication -- the **Information Deficit Theory**. The Information Deficit Theory is based on two assumptions: people probably are skeptical about science because they don't have enough knowledge about the subject and that if scientists pass on that knowledge, the public will become less skeptical (Wynne, 1992).

Information Deficit Theory

As we can see, this model is a linear approach to communicating science and it should be one that students and faculty are most familiar with. Information deficit theory states that if someone lacks knowledge, it's because they haven't been informed. Someone with information, then, is tasked with not just informing that person, but also making sure they understand the information. **You know, sort of like what I'm trying to do right now.**

This theory has a lot to like. In the realm of science communication, information deficit theory stresses that scientists translate highly technical information into material or content that regular people can absorb and understand. Information should be as **simple as possible, compelling, clear and accurate**.

Let's make sure we keep these points in mind as we craft our science messages.

However, science communication researchers noted that the information deficit theory failed to adequately explain the times -- maybe even many times -- when the public was informed about the

Theory 2: Low-Information Rationality

We like to think of ourselves as rational info-vores. We collect all relevant information from multiple sources, carefully ingest it, and then rationally come to a decision, or take a stand.

According to low-information rationality theory, that's not even close to how we make decisions (Scheufele, 2013). This theory suggests that what information deficit theory lacks is an understanding of how people actually process information. People are bombarded by information and they don't necessarily like all of the information that they encounter. Therefore, people use shortcuts -- or heuristics -- to take in all of that new info and weigh their responses. Those shortcuts don't always lead to great decisions. People may fall back on religious or ideological leanings to make decisions. Or, they may try to guess how other people feel about the issue. Often, it's the media, itself -- and how the media presents and issue -- that nudges their decisions.

This theory is typically used to explain voting behaviors and decision-making in the public sphere, but it may also apply to how people digest science information. Of course, it makes sense for science and health communication, too. Scientific concepts can use up considerable cognitive resources and that may make people look for shortcuts to help process these concepts. And, in fact, recent research has suggested that these mental shortcuts may help citizens form opinions on scientific issues, including stem cells, nanotechnology and climate change (Brewer & Ley, 2011).

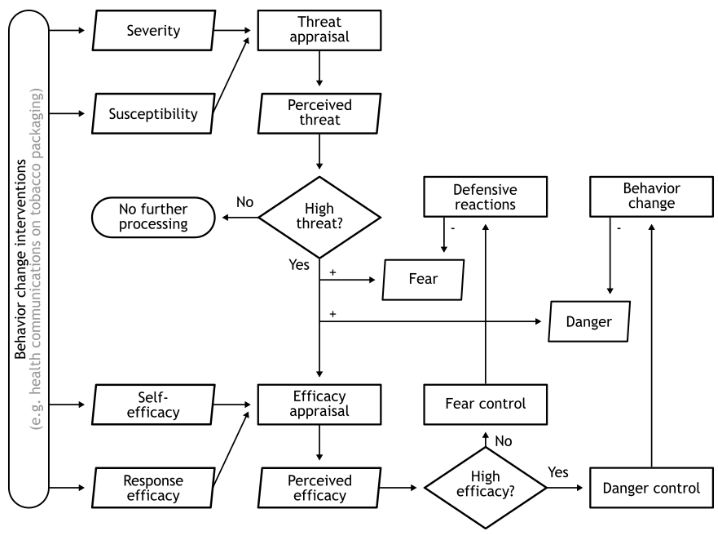
Because of individual differences among science information consumers and the differences in the heuristics that matter to them, along with the different information that you're trying to communicate with them, there is no magic persuasion bullet. However, the low-information rationality theory may help you set expectations when you are holding conversations about science. And this is precisely what it is -- a conversation. Rather than injecting knowledge into a completely open brain, we must get to know our audience, just like we try to understand our friends' backgrounds, experience, and point-of-view when we have a conversation with them.

TAKE AWAYS

- Try to make complex information as simple as possible, so that it doesn't unnecessarily tax the public's cognitive load.
- Respect diversity.
- Be willing to listen.
- Be versatile in your message approaches.
- Avoid triggering heuristics and biases unnecessarily.

Brewer, P. R., & Ley, B. L. (2011). Multiple Exposures: Scientific Controversy, the Media, and Public Responses to Bisphenol A. *Science Communication*, *33*(1), 76–97.

Theory 3 - Extended Parallel Process Model



Remember the simple **Information Deficit Theory** chart at the beginning of the module?

Things have changed!

Perhaps in response to the notion that the Information Deficit Theory was too simplistic to fully explain the public's reactions to health and science messages, the **Extended Parallel Process Model** represents a much deeper, more nuanced description of how these messages are processed (Witte, 1992), particularly a person's response to fear-based stimuli (Often: fear appeals or threat appeals). Often used to study health messaging, EPPM represents the complex way that a message travels from reception of a message to possible behavior change.

And, yep, it also shows us that the path toward science and health understanding can be complicated. OK, it can be downright messy. People are not passive sponges waiting for you to pour your sweet, sweet scientific knowledge into their brains. People have emotions. They have biases and prior experience and knowledge. They'll throw up defenses when they feel cornered or threatened. They want solutions. They might feel empowered, or disempowered.

Exercise 4-1: Feel the Fear

Publish Edit ⋮

Can you find science stories that may trigger fear among readers, listeners or viewers?

Where can you find examples of these fear appeals -- in the headline, in the text, at the beginning of the story, in graphics, etc.?

What about hope? Does the journalist ever offer a way to alleviate that fear? Do they offer some suggestions for help? Do they offer the public a sense of agency or self-efficacy -- that there are ways to manage or handle the problem?

If the reporters didn't, how would you have handled this as a scientist? Is there a way you could have added information or context to give people a sense of agency and self-efficacy?

Points 0

Submitting Nothing

Due	For	Available from	Until
-	Everyone	-	-

+ Rubric

Science of Science Communication Takeaways

Science communication theories offer scientists several best practices for communicating their findings and policy recommendations with the public.

Here are some tips:

Clear and Compelling Conversation
The essence of **Information Deficit Theory** is correct -- Scientists need to pass their findings onto the general public in **clear and compelling** ways. Communicating with a non-technical, non-scientific audience, therefore, requires scientists to use common words, short and precise sentences -- and a vocabulary that is as jargon-free as possible. When complex terms and jargon are necessary, care should be used to explain complex terms and jargon. Using analogies and connecting the science to a person's common experience can make those terms relatable.

Nuanced and Complex
While information deficit theory offers a basic truth in the need to communicate to the public and offers basic ideas on how to communicate effectively, the theory fails to offer a complete picture of the often nuanced -- and sometimes baffling -- ways that messages are distributed and understood. Other models, while not perfect, should give you a better sense of how to communicate with the variety of diverse audiences who are hoping to understand your work.

Does Scaring People Help Them Understand Science?
One of the most common persuasive tactics is to show people the possible negative effects of ignoring their advice. (Parents have been doing this forever!) These are often called fear or threat appeals. However, the scientist should use care when using fear appeals. People respond to fear in many ways and not all of those responses include compliance. In fact, fear appeals may increase denialism, or make a person feel so hopeless that they do not try to act on any advice or policy recommendations. Fear may cause people to shut off and avoid the problem, too. Also, we should consider that fear, itself, could cause possible health concerns -- anxiety, depression, cardiovascular problems -- for the reader, viewer, or listener.

Hope appeals -- **using messages that evoke hope (https://pubmed.ncbi.nlm.nih.gov/25297455/)** -- have also shown persuasive qualities under certain conditions.

Other Important Factors

Remember that people aren't empty vessels that will passively accept each piece of information and act on that information in rational ways. We are complex, emotional, biased individual who respond to new information in somewhat unpredictable ways. Some of those factors include:

Publish Preview Edit ⋮

This quiz is unpublished
Only teachers can see the quiz until it is published.

Test Your Sci-Comm Theory Know-How

Quiz Type	Graded Quiz
Points	4
Assignment Group	Assignments
Shuffle Answers	No
Time Limit	No Time Limit
Multiple Attempts	No
View Responses	Always
Show Correct Answers	Immediately
One Question at a Time	No

Due	For	Available from	Until
-	Everyone	-	-

Preview

Code Book

Level of Analysis

Analysis will be completed at the comment level for comments posted by students on the Science Writing and Science Communication student introduction message board over three sections of the course page.

Variables

Topics

Each comment should be coded as one category. For those that may fit more than one, choose which is the dominant meaning of the comment. If there is no clear category, the comments can be coded as 0. Instructor comments were rated a 0.

Science Communicator as Activist

1. **R**emarks on activism and advocate
    a. Includes comments that are trying to correct wrongs or misperceptions
    b. Includes comments on causes or allegiance to specific scientific topics, for example climate change, vaccines.
    c. Includes comments on dire consequences if the cause is not espoused by science communicators.
    d. Includes comments on personal connections to causes.
    e. E.g. "Climate change must be stopped, and we need to tell people how." "I'm worried that people think psychology is just listicles and pop psychological drivel. I want to change that."

Science Communicator as Enthusiast

2. Beauty and Nature
    a. Includes comments of awe on how science and discovery
    b. Includes comments on specific aspects of nature that causes awe, such as the intelligence of animals, or the adaptations of insects.
    c. Includes statements on love of natural world.
    d. Includes statements on communicating their own scientific research with the world.
    e. E.g. "I just love camping and getting out in nature, seeing beautiful things." "I fell in love octopi after reading an article about them." "I really love science and nature. I just don't want to spend the rest of my life in a lab." "I'm a statistician. And I want to be able to communicate this information to the public."

Science Communicator as Science Journalist

1. Science Journalist

a. Includes comments of working on science pieces for newspapers or magazines, or current occupational status in a newspaper, magazine, online publication, etc.

b. Includes comments on gathering facts about science

c. Includes comments about becoming a journalist or reporter.

d. E.g. "I want to write about research." "As a journalist, it's important to get the facts right." "I plan to become a newspaper reporter."

e. Includes aspirational statements about working in public relations, or current employment status in public relations.

f. Includes statements on working for companies that are science- or technology-based.

g. Includes statements on translating science for the public as a PR professional.

h. E.g. "I would like to get a public relations job in the tech field." "Medical writers get paid a lot."