They’re Smart, but You Can’t Trust Them: Using Communication Principles to Help Scientists to Increase their Trustworthiness in Public Communication Situations

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ABSTRACT: Scientists struggle with creating positive public perceptions with public audiences. This is true despite the generally positive view members of the public hold for science and scientists, including a positive view of the contributions of scientists to society. In fact, members of the public feel separated from scientists, stand in awe of scientists, and are intimidated by scientists (Jacobs, 2011). Rhetoricians and communication scholars can help, as they have been grappling with and refining ways of building trustworthiness, respect, credibility, and connection between speakers and their audiences for centuries, and the communication principles developed through their work are particularly applicable to the difficulties faced by scientists engaging public audiences.

KEYWORDS: immediacy, identification, public science presentations, public speaking for scientists, science communication, self-disclosure, trust in scientists

1. INTRODUCTION

Despite a general agreement on its value and importance, there are many challenges to public communication by scientists. In addition to scientists’ general reluctance to engage in public communication (Ecklund, James, & Lincoln, 2012; Safina, 2012), some scientists do not want to participate because they lack confidence in their public communication skills (Ecklund et al., 2012; Meredith, 2010). Meanwhile Kuehne, et al. (2014) contend that graduate students in science fields are not given adequate resources to learn science communication skills while in graduate school, leaving them unprepared to contribute to science communication activities after graduation. Wynne (2006) posits that scientists hesitate to interact with the public because they believe there is a public distrust of science and their efforts will be unappreciated. Distrust of scientists is documented by researchers in numerous fields, including sociology, science, and communication (Fairbrother, 2017; Funk & Kennedy, 2016; Dudo & Besley, 2016; Wynne, 2006).

Nonetheless, members of the public hold a generally positive view of science and scientists. For example, a Pew Research Center study shows that Americans hold science in high esteem, with 79 percent saying science has a positive effect on society and 70 percent saying that government investments in engineering and technology and basic science usually pay off in the long run (Funk & Rainey, 2015). Another study showed that over 90 percent of Americans believe scientists are “helping to solve challenging problems” and are “dedicated people who work for the good of humanity” (Gannon, 2014). However, even with these positive beliefs about science, members of the public feel separated from scientists, stand in awe of scientists, and are intimidated by scientists (Jacobs, 2011). Additionally, the same Pew Research Center study (Funk & Rainey, 2015) notes that while the public may respect scientists, they do not necessarily trust them, noting that there are significant differences in the public's and scientists' opinions on science topics, such as whether or not it is safe to eat genetically modified foods (Yes: 37% public, 88% scientists) and build nuclear power plants (Yes 45% public, 65% scientists).

Communication scholars and scientists have suggested a variety of ways to address these issues, in particular by increasing communication training for scientists (Heath et al., 2014; Kuehne et al., 2014; Neeley, 2013; Nisbet & Scheufele, 2009); rhetoricians focused on public speaking can be valuable assets in these efforts. In fact, rhetoricians have been grappling with and refining ways of building trustworthiness, respect, credibility, and connection between speakers and their audiences for centuries (Lucas, 2012; Aristotle, 2001) making the communication principles developed through their work particularly applicable to the difficulties faced by scientists engaging public audiences.

This study attempts to distill the expertise developed by rhetoricians into advice that can be used by scientists to improve their credibility and trustworthiness with public audiences. The study explores the most desired skills for scientists to display when interacting with public audiences as put forward by scientists, science communication scholars, and science societies, such as building trust and creating personal connections. It then applies the most highly recommended public speaking techniques for building credibility and trustworthiness in the context of public communication to the challenges identified in order to suggest practical, applied communication skills that scientists can learn and practice that will increase their credibility with audiences. Some of the communication concepts include immediacy, identification, analogies, and self-disclosure. This information was compiled in the process of developing a rubric and accompanying code book used for the assessment of scientists when speaking to public audiences.[1] These instruments are included in the appendix for the reference of the readers.

The information in this manuscript and in the rubric are particularly well-suited for use in programs that train scientists to communicate with public audiences. As training programs are being increasingly encouraged and developed, these suggestions can be used as tools to facilitate integrating the communication expertise of rhetoricians and communication scholars into public communication training for scientists.

2. METHOD

Before determining which communication principles are of most value in helping scientists increase their trust with public audiences in public communication situations, it was necessary to identify what scientists want to accomplish in those situations. To "gather substantive information about the domain of interest (scientists communicating with public audiences) that (would) have direct implications for the assessment" (Mislevy & Haertel, 2006, p. 4) it was necessary to conduct a domain analysis of the field: scientists communicating with the public. To do so, I first looked at what scientists are saying and being told about communicating with

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[1] Called the APPPS Rubric: An Assessment for Public Presentations by Scientists. An outline of the development of the rubric and code book; see Murdock (2017).

public audiences and what they should do when communicating with public audiences. This was accomplished by first, examining what scientific societies and authorities say to scientists and second, by examining the academic literature in science communication. Rather than ask scientists what they like about communicating with the public or what *they* want the public to understand or gain from hearing public presentations by scientists, the current study looks at normative instruction: what science societies, government agencies with an interest in science communication, and science communication literature says that scientists should accomplish or attempt to accomplish when communicating with public audiences.

This study focuses on the knowledge, skills, and abilities most useful in making presentations to groups of people in an educational/informational setting, such as a library or community center, rather than other public presentation situations, such as making persuasive presentation about policy to a group of legislators. This "library talk" situation is a common context for scientists to encounter (Kent, 1984).

Science societies were chosen from the list of 252 affiliates of the American Association for the Advancement of Science (AAAS) in addition to the AAAS itself. The AAAS is the largest general scientific society in the world, and therefore the largest in the United States. The criteria it uses to determine whether an organization can be considered for affiliate status include a size requirement (200 members) and a longevity requirement (at least 5 years of existence). This vetting process ensures that any organization examined will be of significant import. The standing of the AAAs in science circles in the U.S. also makes it likely that any scientific society of any standing and importance will apply for affiliate status. Additionally, three government agencies deeply concerned with the public communication of science were included in the sample: The National Science Foundation (NSF), the National Institutes of Health (NIH), and National Aeronautics and Space Association (NASA). The artifacts for analysis were gathered from the organizations' websites.

The use of random sampling to gather data resulted in 263 examples of encouragements for scientists to communicate with the public. The qualitative content analysis methodology described in Krippendorf (2013) was used to evaluate the samples, discover themes, and organize the results into categories of knowledge, skills, and abilities desired of scientists who speak to public audience.

For the analysis of academic articles, I completed searches of the "Communication and Mass Media Complete" database, EBSCO Host's "Communication Abstracts" database, and "Google Scholar" for articles that appeared between 1980 and 2016 using 18 search terms touching on science communication, particularly public science communication. When the searches produced 10 irrelevant returns in a row, I ended evaluation for that particular search term. This method produced 62 academic articles that were examined for indications of the knowledge, skills, and abilities authors of the academic works suggested scientists exhibit when speaking to public audiences. These artifacts were also analyzed for themes using Krippendorf's (2013) qualitative content analysis methodology.

Coders[2] examined the website and the articles for for "should" statements – normative reasons given to scientists for communicating with and engaging with the public. After finding

[2] For complete details about the data gathering and iterative analysis methods, see Murdock (2017).

any normative statements (relatively few in number), coders gathered other comments and identified implications about communicating science to the public. For example, when an article highlighted the fact that a researcher took time to create science lessons for middle school teachers, coders inferred that by highlighting this kind of activity the organization was indicating its interest in scientists engaging in public communication to inform publics about science and to increase understanding of science in the highlighted way, in this case, in a formal educational setting.

3. FINDINGS AND ANALYSIS

Similar themes were found in both analysis methods, with a few unique results. The most common knowledge, skills, and abilities found in science society texts and in the review of the literature from first most common to fifth most common were the following:

(1) Increase audience understanding of science/research topics and processes
(2) Engage with the audience in back and forth communication
(3) Interpret and clearly explain science concepts
(4) Communicate the relevance and importance of science
(5) Provide accurate scientific information so people can make good choices

Although there were other kinds of knowledge, skills, and abilities mentioned both on the websites and in the articles, there was a great deal of overlap in the items mentioned most frequently as being of primary importance when interacting with public audiences. After evaluation and analysis, the many knowledge, skills, and abilities mentioned in the domain analysis were distilled into six constructs or desired outcomes for use in a rubric.

The six outcomes are the ones that the domain analysis noted as being most commonly cited by scientists, scholars, and communication experts, those that are mentioned most often by individuals who train science communicators, and those which, based on communication theory and research, are most effectively operationalized for a rubric. Using the aforementioned criteria originally yielded five categories, or constructs, for inclusion in the assessment. During testing, these were expanded to the following six:

(1) Scientists speaking to public audiences will be able to explain the relevance and importance of the science information to the specific audience to which they are speaking.
(2) Scientists speaking to public audiences will be able to use language to express complex ideas clearly and in a manner that is adapted to the understanding of the audience to which the scientist is speaking.
(3) Scientists speaking to public audiences will use visual aids, particularly electronic visual aids, in a way that enhances their presentations by following applicable guidelines for speakers with technical expertise who are creating visual aids for non-expert audiences.
(4) Scientists speaking to public audiences will explain one or more science concepts and processes such as steps in an experiment, data gathering, uncertainties in science, and/or the team nature of science exploration.
(5) Scientists speaking to public audiences will present themselves and scientists in general as trustworthy, friendly, approachable, and knowledgeable.

(6) Scientists speaking to public audiences will engage audiences in interactions and conversations about science.

The domain analysis illuminated some specifics outlining why the skills and abilities mentioned above are thought to be crucial for scientists to develop.

3.1 Relevance and Significance of Science Information

The ability to relate to a specific audience is an ability commonly assessed in public speaking (Lucas, 2012). However, scientists have a particularly difficult job when it comes to this skill. Broadly, a general public speaking assessment looks for the speaker to create what is called "identification," or some connection between the speaker and the audience (Burke, 1969). The speaker talks about specific experiences, ideas, values, or stories that are similar to those experienced or believed by audience members. This connection helps the audience members feel that the speaker is similar to them and understands their needs, interests, and concerns.

The difficulty of this task is heightened when the speaker is a scientist, however. The perception of difference is wider between the public and scientists than it is with experts from other fields (Rosenberg, 2006). As noted previously, even though Americans hold scientists in high esteem, they often do not follow scientists' suggestions and often feel that scientists do not understand them and their lives (Funk & Kennedy, 2016; Rosenberg, 2006). This means that from the outset, the audience members sense a separation rather than similarity between themselves and the scientist. The audience member knows that that the scientist has years of schooling and research experience, which make the scientist very *unlike* the audience member in many ways. Therefore, the scientist as speaker needs to show the audience that he or she *is* like the audience member in at least some ways, and that the scientist 1) understands the audience members' level of expertise on the subject, 2) can help the audience members understand this science topic as being relevant and important to the audience their lives, and 3) can help the audience members to see science as interesting, appealing and exciting.

In the domain analysis, scientists and science organizations also frequently indicated that explaining complex ideas clearly should be an outcome of public communication by scientists. As an example, one website from the American Geophysical Union talked about their how their Sharing Science program emphasizes eliminating jargon from the vocabulary of scientists speaking to the public, noting that words that have a specific meaning to scientists may have another meaning to members of the public (Hanlon, 2016). By applying communication theory and science metaphor research, it is possible to assist scientists in communicating complex science clearly and in a way that is accessible and understandable to members of the public.

3.2 Using Visual Aids Appropriately

Skillful use of visual aids was another point of emphasis in the domain analysis. PowerPoint presentations are now *de rigueur* for scientific presentations to peers, and scientists can use PowerPoint effectively for lay audiences as well. However, scientists may not immediately see the need to use different techniques than they normally use for scientific presentations in order to create PowerPoint slides that are effective for public audiences. However, it is important that scientists eliminate some of their most common techniques for creating visual aids when they present to public audiences. Research shows that scientific presentations, particularly scientific presentations to the public, can be confusing to the audience, and complex visual aids add to the confusion. The speaker needs to make explicit assertions and explain things clearly, both orally and visually, if they are to help audiences understand complex ideas (Alley, Schreiber, Ramsdell, & Muffo, 2006).

3.3 Sharing Scientific Knowledge

The most often mentioned desired outcome or skill that the domain analysis revealed was the desire for scientists to share information about science and the processes of science with public audiences.

Despite the finding that scientists are encourage to share scientific knowledge, there are many critiques of the basic sharing of science information. Some scholars say that simply sharing information, which is called a "deficit" interaction, is not an effective way of engaging the public's interest in science or even increasing the public's understanding (Nisbet & Scheufele, 2009; Wynne, 2006). However, as evidenced in the domain analysis, large numbers of scientists remain convinced that more and better explanations of science to the public will help scientists accomplish their other goals (Davies, 2008). And the fact remains that scientists do know more about science processes and outcomes than the non-scientist, general public. Therefore, even interactions with scientists that emphasize the "public engagement with science" that is more popular among science communication scholars (Jensen & Holliman, 2009) there is a need to start with the public getting some information they did not already have. As William Bodmer (2010), who was instrumental in promoting science communication during its years of rapid growth in the 1980s, argues, engagement with science cannot come without some kind of understanding of the science being discussed.

3.4 Establishing the Relevance and Importance of the Science Being Communicated

Not only did scientists and science scholars analyzed for the domain analysis advocate for more communication of basic science information, but they also wanted the processes and thinking of scientists shared with the public. Throughout the domain analysis, scientists and scholars argued for sharing a better understanding of science and science processes. For instance, when a scientist hesitates to claim that something is a "fact," some members of the public believe that an issue is still under debate, when in fact, the culture of science is to always acknowledge there are unknowns, even when a question is generally settled (Ceccarelli, 2011). Many scientists believe scientists in general have a responsibility to make this kind of information clear to publics (Fischhoff, 2007), and believe that being open about the processes and values that underlie science will increase public trust in scientists (Irwin, 2009). Some scientists also believe that scientists should be actively involved in correcting misinterpretations of science and in being honest about what scientific and technical advances can and cannot do (Lackey, 2007). Other scholars claim that "stripping away" the air of mystique that surrounds science and helping members of the public see science as a difficult, messy process will help the public respect scientists more as people and also understand better the way science changes and develops (Fabj & Sobnosky, 1995).

In the domain analysis, I found comments such as this one from the American Water Resource Association: “We found that our focus groups were relatively uneducated about science in general and about environmental issues in particular. Once their awareness of those issues was raised, however, their interest also appeared to increase” (Halverson & Burton-Radzely, 1999), and this one from the National Speleological Society: “Instead, let it do what it is best equipped to do: bring science to the non-scientific public”(Palmer, 1996). Others argue that the public needs a better understanding of both statistics and risk (Bodmer, 2010) and that the public should better understand the place of uncertainty in science.

For these reasons, communicating information about science processes, choices made by scientists, uncertainties of scientific findings, results of studies, and descriptions of the scientific processes (and how the actual process of “doing” science may differ from the “scientific process” taught in K-12 situations), among other topics, are important tasks in which scientist should engage (Hilgartner, 1990; Miller, 2003).

3.5 Increasing the Public Perception of Scientists’ Trustworthiness

Although all of the six constructs noted in this study will help scientists build trust with public audiences, in the domain analysis, one of the skills scientists were specifically encouraged by science societies and scholars to develop was increasing their trustworthiness and credibility with public audiences. To illustrate the need for scientists to build trust with publics, a study in 2005 (cited in Rosenberg, 2006) found that teenagers viewed scientists as valuable, but “not like them,” and “not normal and attractive men and women.” When asked to sketch a scientist, most drew a person with a headful of crazy, white hair, lab coat, and thick glasses, as shown in a 2006 study (Rosenberg, 2006). Since the 1960’s, the public’s perceptions of scientists have been that scientists are difficult to comprehend and odd (Rosenberg, 2006).

Therefore, although scientists enjoy respect, they do not necessarily enjoy trust and credibility as persons who have a good understanding of the world the “rest of us” live in. Therefore, it is important that scientists use specific communicative practices to increase the public’s trust in scientists when they speak to public audiences and increase the public’s perception that scientists are “normal” people who are personable and have the well-being of others in mind.

A significant body of communication research shows that public audiences are much more willing to listen to and accept the arguments of people that they deem as credible or trustworthy. In addition, the public is more trusting of people who seem more “real,” “human,” and similar to themselves. This trustworthiness boils down to the communication concept of credibility – judgments made by the perceiver (or recipient of a message) that the communicator is believable. The elements of credibility as outlined in communication research are competence, trustworthiness, dynamism or charisma, and composure (Benoit & Strathman, 2004). Dynamism and composure are encompassed in the delivery construct of the public speaking portion of the rubric. However, specifically building trust and connection to an audience is of special concern to scientists, and numerous studies show that there are specific things a speaker can do to increase these elements of credibility.

3.6 Engaging with Audiences

Finally, the scholarly conversation surrounding the public communication of science has been dominated by the concept of public *engagement* with science as opposed to the public *understanding* of science for a number of years. As previously mentioned, the public understanding of science (PUS) model of sharing science information is known as the deficit model: the public has a deficit of knowledge; the scientists fill that deficit. This model discounts the knowledge, interest and intelligence of the public, focusing entirely on the specialized knowledge of the scientists. The deficit model is linked to what Holliman and Jensen (2009) call "first order" or "top down" interactions. The goal of this type of communication is often that the public understand and accept the scientist's perspective. This model of science communication, while still practiced, is panned by critics (Irwin & Wynne (Eds), 1996).

Critics propose a more interactive approach to science communication. The concept of PES (or PEST – Public Engagement with Science and Technology) is a goal articulated by critics and practitioners round the world, as noted by several researchers (Armstrong et al., 2013; Irwin, 2009; Russell, 2010). Broadly stated, the goal of this kind of public communication of science is a two-way communication between scientist and public, where the scientist gains from the public's perspective and the public gains from scientists' perspectives through interactions, as opposed to the public passively listening to the scientist. Recent research increasingly points to the goals of PES or PEST as being the most helpful and productive goals for science communication. For example, the Center for Advancement of Informal Science Education suggested in a 2009 report that public engagement with science is a worthy goal for many informal science communication encounters. The PES(T) model suggests that while publics need to learn science to participate in modern society, in science communication situations the "focus should be on the valuable perspectives and knowledge publics bring from their lives that enhance the discussions of science and issues of science-related societal issues" (*Many experts, many audiences: Public engagement with science and informal science education*, 2009). Meanwhile, the worthy goals that scientists have for PUS science communication may also be reached through PES(T) science communication.

Different researchers have categorized interactions between scientists and the public differently. Jensen and Holliman (2009) offer a model similar to those proposed by other researchers, dividing the interactions into First, Second and Third order interactions. First Order interactions follow the PUS or deficit model, with a member of the public interacting with the scientists in a way that privileges the scientists and maintains his or her position of power. This might be a standard question/answer interaction where the member of the public asks a question and the scientist answers the question from the position of expertise, or it might involve a scientist inviting a member of the audience to participate in an activity or an experiment by holding, pouring, touching or throwing something. A second-order model envisions a discussion, a two-way interaction between scientists and the public where the two parties have more of a symmetrical relationship, an interaction that would be considered PES(T). This kind of engagement requires more accountability on the part of the scientists and the public, and operates on more of a consensus basis than first order interactions, with scientists not necessarily being granted privileged status automatically, although such privileging may occur during the interaction (Jensen & Holliman, 2009). On the other hand, third order interactions involve scientists and publics engaged in a deliberation and debate, together setting the agenda for discussion. When interactions are third order, there is not only input from the public and interaction with the scientist, but there is also disagreement and critiques from the public that are accepted and processed as valid by scientists.

Jensen and Holliman (2009) say that rather than seeing them as problematic or threatening, scientists who engage in third order interactions find disagreement and critical discussion on the social implications of science as being "societal resources to be valued" p. 38). An example of second and third order communication took place in the U.K., for example, when the government organized deliberative forums to discuss genetically modified foods and their place in the food chain and organized sessions to deliberate about nanotechnology and how it would be used in society. The participants for these groups were carefully chosen and invited to attend the discussions. Participants included members of the public from a range of demographic backgrounds as well as scientists and other specialists (Irwin, 2009).

Despite the emphasis from researchers, scholars, and some government officials on second and sometimes third order communication, there is still a preponderance of deficit model communication taking place during science communication interactions, including many informal science interactions (Davies, 2008; Russell, 2010). However, the domain analysis showed that not just researchers but also scientists and science organizations value engaging interactions when scientists communicate with the public. Therefore, this rubric includes a construct that measures the ability of scientists to interact with members of the public as an aspect of public science communication that should be assessed

Successfully accomplishing the goals outlined above will help scientists build connection and therefore trust with public audiences. While each communication situation is unique and no results are guaranteed, studies have shown that there are specific behaviors science communicators can learn that will help them fulfill their aims for public science communication. The remainder of this essay provides suggestions outlining specific communication knowledge, skills, and abilities that can help scientists reach these goals.

4. FINDINGS: APPLYING COMMUNICATION PRINCIPLES TO PUBLIC PRESENTATIONS BY SCIENTISTS TO HELP BUILD THE PUBLIC'S TRUST IN SCIENTISTS

Each of the six outcomes identified as desirable for public presentations by scientists can be developed by scientists learning and implementing specific communication skills and applying communication principles.

4.1 Establishing the Relevance and Importance of the Science Being Communicated

Establishing the relevance and importance of specific science concepts can build the audience's trust in scientists when audience members see that scientists are similar to them and share similar values and interests (Palmer, 1996).

To create identification (Burke, 1969) with the audience, the scientist needs to know the audience as well as possible. Prior to giving a public presentation, scientists should use all available resources–such as demographic compilations, the knowledge of the person who invited them to speak, conversations with potential audience members, documents about the community or group that will be invited, etc. – to discover general values, characteristics, and ideals of the audience.

When speakers are demonstrating expertise in creating identification, they will include elements in their public presentations that help audience members see the relevance of the science topic to their own lives. To do so, the speaker will emphasize values, goals, and/or experiences that the scientist speaker and the audience member may have in common, as suggested by Burke (1969). The speaker should call attention to the areas (s)he has in common with audience members, not just as a person, but as a scientist (Larson, 2012). Scientists will describe how and why the science they pursue is relevant to the audience to whom they are speaking and encourage agreement about the joy and excitement of science through relating that excitement to the values of the listeners. As theorized by communication scholars, the scientist will avoid areas of disagreement, particularly at the beginning of the presentation, and instead focus on how the scientist's point of view is "consistent with what they (the audience members) believe" (Lucas, 2012).

Some of the values scientists may emphasize are hard work, trying many times to "get it right," making life better for people, preserving an animal species or habitat, creating renewable energy sources so people are able to continue having the convenience of electrical power or the convenience of a personal automobile, experiencing the excitement of discovery, helping people who have surgeries enjoy better results or quicker recoveries, helping the military function more efficiently, and feeding the hungry in our own country or third world countries. The values that will have the most impact will differ between audiences, but the scientist should specifically plan to learn about their audience and appeal to values that will create connections and emphasize similarities.

4.2 Communicating Complex Scientific Ideas Clearly for Public Audiences (Use of Language)

Science concepts can be complex and difficult for non-experts to understand. In fact, as earth scientist and science communicator Roger Aines (2016) points out, many magnificently intelligent people may know little about science. Additionally, even scientists often do not understand the work of other scientists outside a particular area of expertise. Each specialized area of science has its own jargon and "paradigm," as Thomas Kuhn (1970) suggests, and scientists learn their own language as well as laws and theories that provide an explanation of the world that is understood by those initiated into that paradigm. Aines (2016) says, "It may be funny to joke about 'drinking from a fire hose' when a presentation is incredibly dense, and we scientists enjoy the challenge of absorbing information at a high rate. But that metaphor is entirely too apt when applied to a non-scientist. You can't drink from a fire hose – almost all the water escapes you, even if you get some" (para. 17). He also points out that scientists who fail to explain ideas clearly for an audience that is uninitiated into the paradigm will not be heard.

As a result of their training and the nature of the work, scientists naturally use complex, technical vocabulary when they speak about their work. One useful construct that can be used when discussing this phenomenon with scientists is Communication Accommodation Theory or CAT, a communication theory developed by linguists, communication experts, and psychologists. This theory explains communication as not only the exchange of information, but also as a means of managing interpersonal and intercultural communication (Gallois, Ogay, & Howard, 2004, p. 123). Being part of the scientific community is indeed being part of a particular culture, with its own mores, language, idioms, expectations, and traditions. CAT postulates that communicators will adapt their speech patterns to be similar to people they admire, by whom they wish to be admired, and who they want to be like. A speaker will adapt to the language patterns of the admired group to gain social approval and maintain a positive social identity as well as for communicational efficiency (Gallois, et. al. 2004, p. 126). Therefore, scientists develop a way of speaking that is unique to the scientific community, and new members of the community adapt to these language patterns as they seek to be accepted by the community. Each scientific specialty has its own set of vocabulary or jargon unique to its specialty, in fact, and scientists who want to join a particular specialty soon learn the appropriate jargon in order to fit into the social structure. This way of speaking becomes intrinsic so that the scientists do not recognize the exclusivity of their terminology. They are so immersed in the culture of their specialty that the communication patterns are not apparent to them anymore.

However, this causes a difficulty when these experts seek to communicate their science to the general public. Even when addressing audience members as if they are "intelligent but uninformed," as experts are often counseled to do, scientists are so ingrained in their way of speaking and in using the “proper” terminology for the technical instruments and substances used in their everyday work that they fail to recognize that a lay audience does not have the same expertise.

Another concept useful in making scientists aware of their language is the concept of intrinsic knowledge. Technical writers describe those with intrinsic knowledge that they are unaware they have as Subject Matter Experts or SMEs (Hughes, 2002). Scientists are SMEs in their particular specialty and often cannot conceive of less technical or jargon-filled words to describe what they are trying to say without making specific, pointed efforts to do so, sometimes with assistance from non-experts. It has been such a long time since these instruments, concepts, and substances were unknown to them by their technical names that the scientist cannot fathom any other way to describe them. Therefore, when a scientist tries to talk to a lay audience or an audience outside his or her area of expertise, they use language that causes more confusion than clarity. Therefore, a scientist who identifies as a member of the group of scientists in a particular field wants to use the language, the jargon, and the terminology that allows acceptance into that exclusive, desired group. As scientists conform their language to the language used by this desired group, the use of those terms becomes second nature, intrinsic, and unknown. Therefore, when those scientists speak, their language is difficult for non-experts to comprehend, creating distance between audience and speaker and confusion in the audience.

Practiced public communicators of science, however, use communication accommodation in a different way. While they do use scientific terms, they use the terms sparingly and carefully, often with definitions. They want to be liked, appreciated, and welcomed by the general public, the “non-expert in science” public, so they accommodate their word and language choices to be more like the group they admire and from which they desire admiration – the non-scientific public (Murdock, 2013). Scientists speaking to a public audiences can improve their language use by imagining themselves being liked an admired by the lay audience to whom they are speaking and using the language that will help them accomplish that goal.

Another tendency that can hamper the ability of scientists to communicate with public audiences is the practice of virtual witnessing (Shapin & Schaffer, 1985). In presentations by scientists who are practiced in public presentations, speakers refer to and demonstrate objects, people, and places the audience is familiar with -- such as deserts, fruit, European villages, and baseball games -- which the scientist speakers relate to science concepts. Shapin and Shaffer (1985) note that presentations by less public-oriented scientists often limit their references to labs, measuring equipment, or data gathering in scientific settings. These scientists choose their language out of concern for following accepted scientific mores and standards, for describing the work they do in a way that gives assurance that the experiment was conducted properly, under correct conditions, and therefore reaching reasonable results. The language used by these scientists shows concern for presenting their experiments and results as "true" science. Scientists who focus on elaborating the details of lab procedures, on describing the actions of the scientist, or on showing the technical results of an experiment in PowerPoint slides full of complex verbiage and figures may be focused on providing this virtual witnessing experience for the audience. In order to convince the audience that there is "real" science behind the work, they believe that the work needs to be couched in rhetorical terms that sound official, objective, and obscure – that sound like "real" science.

Rather than be concerned with virtual witnessing, scientists engaging with public audiences can be reassured that members of the public already assume them to be experts and understand their work as legitimate – the public has a respect for scientific work. Therefore, instead of focusing on the scientist's need to be seen as a "true" or "valid" expert, scientists speaking to public audiences could change their focus to concentrating on the audience's need to understand. This understanding requires interactions with members of the public and practice with presenting to lay audiences. Communication specialists can be valuable in these practice sessions, as they are just the type of intelligent but non-expert audience member the speaker is trying to reach and they have communication expertise to offer.

As an example, *Salon* writer Heather Havrilesky (2003) describes the approach of well-known public science communicator Carl Sagan in this way:

> "Explaining everything is difficult. That's why Carl Sagan was always walking around Spanish villages in period costumes or making solar systems out of fruit. He was trying to give us the lowdown on electrons and nuclear physics and black holes, and if you can't demonstrate such things using complicated, head-spinning formulas, then you have to hang some oranges and apples from the ceiling and smash stuff with baseball bats." (p. 1)

When scientists communicating to the public are freed from the perception that they need to establish their credibility as scientists, they are able to use bicycles or baseball bats, cut up pieces of cheese or place models of atoms in the desert to help their audiences conceptualize complex principles. When a scientist is overly concerned with establishing his or her own credibility or the credibility of the work they are doing, they rely on the language of virtual witnessing, which makes audience understanding more difficult.

Certainly, scientists speaking to public audiences need to use clear, understandable, accessible language that is free from complex vocabulary or jargon and that acknowledges the interests and knowledge of the audience while being aware of the scientist's status as a subject matter expert. In addition, there are other language techniques that can also help scientists' language be understandable to their audiences. For example, studies such as those completed by Knudsen (2003), Boyd (1993) and Cat (2001) show that metaphors, comparisons, and analogies are good ways to explain complex scientific principles to lay publics. Metaphor in the linguistic tradition focuses on the Theory of Cognitive Linguistics, which has developed over the past approximately three decades. This theory sees metaphor as something that "permeates daily conventional language" (White, 2003, p. 132) and infuses all conversation and language. Lakoff and Johnson (1980), for example, note that the metaphor “argument is war” is so deeply embedded in our modern culture that we habitually use war metaphors to describe arguments and what we do when arguing (such as “winning” a point, “attacking” a weak point, or “retreating” from an unsuccessful argument) and we have difficultly thinking of argument in any other terms (for example, a negotiation or a collaboration) (pg. 4).

Cat (2001) notes that there has been some historical bias against metaphor in science communication, but scientists now are often encouraged to use metaphor to explain difficult concepts. In one example of this work, Boyd (1993) proposes that scientific metaphors should be divided into two different types of metaphors. One type is generative or theory-constructive metaphors that are generally used in scientific discourse within the science community and which cannot be paraphrased because there is no other way to talk about a particular phenomenon (such as “the genetic code.”). There are also pedagogical or exegetical metaphors such as “messenger RNA” used to explain or illustrate a “scientific phenomenon for which a perfectly adequate, alternative original expression exists” (Boyd, 1993, p. 485).

While Knudsen (2003) disagrees with Boyd’s (1993) distinct delineation between the two types of scientific metaphor, she does say that the development of metaphor in scientific situations differs from the application of and development of metaphors in everyday situations. In fact, Knudsen’s (2003) own work expands the research into science metaphors to examine how metaphor is used in communication to public, non-expert audiences by examining metaphors in science journal articles and comparing them to articles in a science magazine for lay readers. She shows that the metaphors in science move back and forth between theory-building and pedagogical so that the strict delineations Boyd (1993) suggests are impossible to make. Nevertheless, she says, metaphors can have strong explanatory power.

Typically, the metaphors scientists consciously use to explain their work to lay audiences are pedagogical metaphors. Scientists use them to compare a scientific concept or process unknown to the audience with something that is known to the audience. However, scientists may also use cognitive metaphors – those metaphors that are unconscious and permeate regular conversation and speech. For a scientist, these subconscious metaphors are different than those of a lay person since the scientists’ cognitive structure and experience differs from that of a lay person. For example, a neuroscientist might describe the brain as a vessel or as an independent agent (“his brain turned on him”) where such descriptions may not make sense to a lay person who has not studied the brain in the same way or with the same assumptions (Knudsen, 2003).

Studies show that the use of deliberate, pedagogical or teaching metaphors is more effective for clarifying complex ideas than are the cognitive or subconsciously-used theory-building metaphors and show that the use of one consistent metaphor is more effective than the use of multiple metaphors (Knudsen, 2003). For example, I assessed audience reaction to some of the presentations made by scientists which were assessed for this study. In one of these presentations, a scientist speaking about polymers called them “chains” “strings of beads” “building blocks” “networks” and “systems” – five different metaphors for the same item in a single presentation – and also personified the polymers by saying the molecules in a polymer “liked” or “didn’t like” one another. Audience feedback forms showed that audience members found that the speaker who used these varied metaphors was unclear. Conversely, a speaker who used one metaphor consistently throughout a presentation was given high scores in clarity, and, on feedback forms, audience members mentioned the single metaphor as helping with clarity. Therefore, the rubric instructs assessors to listen for comparisons, and instructs assessors to pay attention to deliberate analogies or metaphors that are clearly meant for teaching.

Metaphors and comparisons combined with accessible vocabulary and concrete description can help make complex ideas and results accessible to public audiences.

4.3 Use Visual Aids, Especially Electronic Visual Aids, to Increase Audience Understanding

Another way scientists can add clarity to presentations is by using helpful visuals, and this assessment looks for visuals that add clarity to a presentation. Therefore, scientists using PowerPoint should consider not only scientific principles but also design principles when creating presentations, particularly when creating presentations meant to increase understanding in public audiences. Research by Tufte (2003), Doumont (2004), Alley & Neeley (2005), Mackiewicz (2007, 2008), and Durso, Vlad, Burnett & Stearman (2011) does not always agree on details, but does agree on broad, overall suggestions about clarity in scientific visuals.

First, visuals accompanying oral communication should differ from those for written communication. Second, slides should not serve as speaker notes. Ideally, slides addressing technical topics should contain a short sentence or two (no more) and a visual element that contains a "visual argument," or support for the text (Alley & Neeley, 2005; Alley et al., 2006; Gross & Harmon, 2009). One study specifically found that visuals that are highly integrated with the text got more attention and were remembered longer than those that were decorative or less integrated with the text (Slykhuis, Wiebe, & Annetta, 2005). There should be no text on a slide (including lists or bullet points) other than the explanatory sentence or two at the top unless it is necessary to support the visual. The "headline" sentences should be written in active voice, using a positive, rather than negative, tone. As a whole, the slides should support an overall message, with at least one article suggesting that presentations use narrative organization. While I do not suggest that every scientific presentation to a public audience should use a narrative pattern of organization, it is ideal for the slides to have a unified feel with an overarching theme to clarify and support the oral presentation.

Any charts or graphs should be simplified, and the detailed labels and tick marks removed. Scatter plots are confusing to audiences and should be avoided, as should stacked bar charts and three-dimensional charts. Simple bar charts and line graphs are easily understood by lay audiences. Pie charts should only be used when there are three or fewer categories being represented in the graph (Tufte, 2003).

Fonts can be serif or sans serif but need to have a professional appearance. Gil Sans and Souvenir Lt. are top fonts for clarity and professionalism, as are Tahoma, Arial and Verdana. Fonts should be no smaller than 22 points for text and 16 or 18 points for references, legends and labels (Durso et al., 2011; Mackiewicz, 2008). Color and animation (other than color photos, which are effect as visuals) should be used sparingly and only for effect. There should be a good contrast between the background and the text on the slide, but speakers should avoid the red/green color combination, 3-D graphics, and excessive shapes and colors on a single slide or throughout the presentations (Durso et al., 2011).

These recommendations may contradict advice scientists are given by fellow scientists but are supported by communication and technical communication research. Scientists speaking to public audiences should keep in mind that the visuals for a public audience need to be constructed differently than visuals for a scientific audience, particularly one made up of fellow experts in the field. Standard advice for good PowerPoint construction also applies, such as using a consistent color and design theme throughout the presentation, using limited numbers of fonts and colors (speakers should use the same two or three fonts and colors throughout the presentation) and making the visuals simple, legible, and interesting.

Scientists can also benefit from the advice to turn off the visual (usually by inserting a blank slide or using a remote control to shift to a black or white screen) when the visual is not applicable to what is being said. A blank screen returns the audience's attention to the speaker, and helps speakers maintain the attention of the audience.

4.4 Increase Audience Understanding of Science and Science Processes (Specifics About Science)

While the previous criteria primarily address the use of language and the use of visuals, this criterion looks at the ability of the scientist to help a member of the public understand more about the processes of "doing" science. More than just simplifying language or explaining her or his own research clearly, it is important that the scientist add to the public's understanding of the methods, practices and processes of scientific experiments

For example, a scientist talking about the theory upon which they base their work could explain that a theory is not just a guess, but instead is a logical attempt to explain observed phenomenon and predict outcomes. Theories may be confirmed, and if they are, they become important tools for scientists. A scientist could explain briefly how the theory (s)he uses developed over time and perhaps how an older theory was superseded by the current more accurate or comprehensive theory (Siegfried, 2014).

A recurring theme coming from scientists is that the public should understand that scientific discovery or movement does not happen in a bubble – the image of the isolated scientist working isolated in the lab into the night is a largely inaccurate one. Therefore, scientists speaking to public audiences should acknowledge the contributions of other scientists whose work they used to build their own research, they should point out the help of the lab techs and field techs, recognize the statisticians who help with data analysis, and acknowledge the other scientists who have expertise in various aspects of the project. Simply mentioning the other members of a group that assisted the scientist when gathering data, showing a photo of several scientists working together on an experiment, or discussing how scientists talk together about how to solve thorny problems indicates to a public audience that science is a team effort.

Scientists can also tell an audience about how they gather data. For example, the Archeological Institute of America (AIA) suggests that scientists show and/or explain their methods of gathering data through bringing actual data gathering instruments to a presentation or showing photos and videos of the process. Watching or seeing photos of data gathering is engaging to audiences and helps them understand how science work is actually done (Maskas, 2014). Understanding more about how scientists gather and record data makes the science seem less mysterious and more concrete to the audience.

Similarly, brief explanations of how scientists make decisions can help public audiences understand science as an incremental process. Talking about choices such as deciding what questions to explore, what data to gather, and what materials to use to gather them helps audiences be aware that first, there are many different options available to a scientist making these decisions, second, that many different decisions need to be made wisely at each step, and third, that each of the decisions have consequences for how the science is carried out and what information the project will gather.

Lastly, helping audiences have a realistic view of uncertainty and risk is considered important to the public communication of science. Scientists can explain how certain or uncertain a particular concept is or how much there is to learn in that area of study. Scientists by nature tend to hedge on saying anything is "known" or "certain," since additional information could always come to light, but scholars recommend that when talking to a public audience, scientists be clear about which approaches and understandings enjoy nearly universal agreement and which are still in the initial stages of explanation. Similarly, scientists often want to present all possibilities that could occur, but publics may not understand some of those possibilities as being remote or unlikely. Scientists should use layperson's terms to make the actual levels of risk more apparent.

Given these findings, scientists speaking to public audiences should talk about the decision-making processes they go through and some of the choices they make to help break down some of the mystery of science, talk about the actual processes of setting up an experiment or study and gathering data, talk about the teams with which they work, and be more direct in talking about what things are more certain and less certain, more of a risk and less so.

4.5 Help Audiences See Scientists as Human, Trustworthy, and Approachable

Colquhoun (2009) believes, as do many of those whose work was reviewed for the domain analysis, that having scientists communicate directly with the public rather than through intermediaries, such as paid corporate or university communication professionals, will lead to increased trust in and a sense of the humanity of scientists. While his general positivity hearkens to the myth that "all communication is good communication," there is, in fact, research that shows that the right kinds of communication between scientists and public audiences can promote trust, connection, and empathy between communicators.

One effective method of building trust and increasing personal appeal is to engage in self-disclosure. Self-disclosure is the voluntary revealing of any personal information to someone who would not otherwise know this information. Such revelations lead to connection, increased trust, and the perception of closeness in a relationship (Wheeless, 1978; Wheeless & Grotz, 1977). Revelations that show a speaker to be vulnerable or fallible or that seem counter to the speaker's self-interest are particularly effective in building a closeness between speaker and listener (Pratkanis & Aronson, 2001; Reis & Patrick, 1996).

Self-disclosure may involve a scientist talking about his or her family, but for this construct of building trust between a scientist and the audience, the self-disclosure should involve the scientist talking about his/her science work. For example, the scientist might tell a story about an event that happened in the lab. One scientist talked about how surprised he and his partners were at how sticky a substance that they developed was. This disclosure made him seem more human and "real" to the audience while simultaneously expressing the "excitement of discovery" aspect of science and making him seem fallible but still competent. All of these things – self disclosure, excitement, and fallibility – can increase the connection between the speaker and the audience. Too much or inappropriate self-disclosure, however, can have a negative effect, so speakers need to be aware of situation and audience and disclose in ways that are appropriate for the context. Too much disclosure of fallibility, for example, can give the impression of incompetence, too much disclosure of personal information can make a speaker seem ridiculous rather than trustworthy.

Another ability scientists can develop that increases their "humanity" and creates a sense of connection between them and their audience is to make use of inclusive pronouns rather than first person pronouns. Therefore, if a speaker uses terms such as we, our, and us, they are perceived as more inclusive, more connected, and more trustworthy. In contrast, using first person pronouns such as I, me, and my gives the perception of arrogance, of individualism, and of distance (Dreyer, Dreyer, & Davis, 1987; Fitzsimons & Kay, 2004).

Additionally, scientists can use concrete, specific, and unambiguous language in their presentations rather than using abstract terms. When a speaker uses concrete words that the audience can understand quickly and easily, the audience perceives the speaker as truthful. The audience is also able to create clear mental images more easily when listening to concrete language. Psychologically, when something is easier to imagine, then it seems to be more truthful (Hansen & Wanke, 2010).

Communication supplies another measure that can increase perceptions of trustworthiness: the principle of immediacy (Baringer & McCrosky, 2000). A principle often invoked in instructional communication when seeking to increase the connection between student and teacher, immediacy identifies several behaviors that tend to increase the sense of psychological availability, warmth, and closeness between people. In the context of the public communication of science, the measures that are particularly applicable include the use of appropriate humor, moving physically closer to the audience, smiling at the audience, and looking directly at the audience (Richmond, McCroskey, & Johnson, 2003). While some of these behaviors may also contribute to the "nonverbal communication" elements of the public speaking score, when considering the goals of science communicators, these immediacy measures also contribute to the trustworthiness and approachability of the speakers as scientists and are important to assess as an element of science communication.

Therefore, using communication skills and abilities such as appropriate self-disclosure, inclusive pronouns, and concrete language can accomplish the goal of scientists of seeming more human, approachable, and trustworthy to public audiences.

4.6 Engage with Public Audiences in Interactions and Conversations

Numerous scientists and science scholars advocate scientists engaging with the public in ways that involve conversations, questions, and mutual learning – both the public learning from the scientists and the scientists learning from members of the public. Wynne (1992) proposes that rather than considering themselves the "experts," scientists should learn from the lay people who are involved in science-related situations, trusting their social networks, relationships, and identities as much as the scientists trust their science. Other researchers encourage scientists to find ways to share the traditional authority of science with the public by inviting them to make decisions about what is discussed. Davies (2008) notes that scientists may believe that audiences are not interested in discussion and engagement, and believe that many members of the public like the "whiz-bang" aspects of science without the boring facts. However, he argues that scientists need to think less about one-way methods of engagement and more about multi-way, context-dependent debate where scientists engage with publics. Therefore, scientists engaging with publics should deliberately encourage the audience to speak, to question the speaker, and to engage in dialogue.

Dudo and Besley (2016) point out that scientists participating in public communication are most driven to engage with the public to defend science from misinformation and educate the public about science rather than to build trust or establish relationships with publics. However, the drive to defend science may not lead to positive interactions with public audiences. Therefore, scientists speaking to the public should quell any defensive instincts if audience members question them and instead should attempt to give useful information while listening to the audience and acknowledging their experiences and understandings. Scientists should avoid the urge to sound authoritarian, as though they are the final word on any question, and instead use techniques such as asking the audience what they understand about a topic or what experiences they have had previous to this presentation. They can then share the scientific perspective on the topic.

Nisbet and Scheufele (2009) suggest that speakers get to know as much about their audiences as possible prior to the event so that the scientist can engage with the audience based on systematic, empirical understanding of the audience's values, knowledge, and attitudes, among other things.

Scientists are encouraged to have the audience answer questions, through raise of hands or voice responses, during a presentation as well as after. Speakers can ask for brief personal experiences from audience members, have an audience member participate in a brief demonstration, or have an audience member touch and describe an artifact for the rest of the audience. These are just a few of the suggested ways a speaker might engage an audience during a presentation. The speaker should, of course, engage in a question and answer period after the presentation as well. Although situations can arise that are challenging to handle, such as an audience member going on too long about a personal experience or an audience that lapses into a prolonged silence rather than choosing to ask questions, the opportunity for the audience to interact with the speaker is one of the primary objectives of science communication opportunities (*Many experts, many audiences: Public engagement with science and informal science education*, 2009), and practice and training will help speakers manage audience interactions.

4. CONCLUSION

Drawing upon the wealth of research, theory, and practical knowledge in the fields of communication, public speaking, and language assessment can help scientists and training programs for scientists to increase the perceptions of trustworthiness that public audiences have of scientists when they speak in public.

One of the primary benefits of this study is that it provides a thorough domain analysis consisting of an extensive literature review of both scholarly and popular documents to discover what specific knowledge, skills, and abilities scientists should demonstrate when they make presentations to public audiences. As outlined in the study, these skills include the following:

(1) Demonstrating the relevance and importance of science to public audiences.

(2) Use language in a way that makes science concepts understandable and clear to the public.
(3) Explain some of the processes, procedures, risks, and methods of doing science so that audiences can understand them.
(4) Skillfully use visual aids to enhance the scientific message.
(5) Increase the public reputation of scientists by portraying them as trustworthy, “human,” good, and “normal” people.
(6) Interact with public audiences through conversation and dialogue.

Scientists can meet the above goals by improving their public communication skills, particularly skills such as self-disclosure, explaining the relevance of science, using comparisons, metaphors, and analogies, and immediacy can help increase the trust public audiences have in scientists.

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