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OPINION

Science Communication to the General Public: Why We Need to Teach Undergraduate and Graduate Students this Skill as Part of Their Formal Scientific Training

Sara E. Brownell[1], Jordan V. Price[2], & Lawrence Steinman[3]
[1]Department of Biology, Stanford University, Stanford, CA, 94305; [2]Immunology Program, Stanford University, Stanford, CA, 94305; [3]Department of Neurology and Neurological Sciences, Stanford University, Stanford, CA, 94305.

Communication of science to the general public is increasingly recognized as a responsibility of scientists (Greenwood, 2001; Leshner, 2003), yet how do scientists learn these skills? While scientists are thoroughly trained in research methodologies, analytical skills, and the ability to communicate with other scientists, they usually receive no explicit training in communication of scientific concepts to a layperson audience.

Though most will agree that it is important for scientists to be able to communicate to non-scientists, this is a difficult skill that many practicing scientists lack, likely due to the combination of increased specialization over time and the absence of formal training in science communication. In this opinion piece, we argue that incorporating formal communication training into undergraduate and graduate curricula for aspiring scientists will enhance the quality of discourse between scientists and the lay public. We will provide general recommendations for those interested in developing basic science courses with an emphasis on communication with a layperson audience, with specific examples derived from our own experience developing and implementing a neuroimmunology course designed to promote science communication skills in parallel with mastery of scientific content.

Why it is important for scientists to be able to communicate to the public

The public must be able to understand the basics of science to make informed decisions. Perhaps the most dramatic example of the negative consequences of poor communication between scientists and the public is the issue of climate change, where a variety of factors, not the least of which is a breakdown in the transmission of fundamental climate data to the general public, has contributed to widespread mistrust and misunderstanding of scientists and their research (Somerville and Hassol, 2011). The issue of climate change also illustrates how the public acceptance and understanding of science (or lack thereof) can influence governmental decision making with regard to regulation, science policy and funding. However, the importance of effective communication with a general audience is not limited to hot-button issues like climate change. It is also critical for socially charged neuroscience issues such as the genetic basis for a particular behavior, the therapeutic potential of stem cell therapy for neurodegenerative diseases, or the use of animal models, areas where the public understanding of science can also influence policy and funding decisions. Furthermore, with continuing advances in individual genome sequencing and the advent of personalized medicine, more non-scientists will need to be comfortable parsing complex scientific information to make decisions that directly affect their quality of life.

Science journalism is the main conduit for the dissemination of scientific information to the public. Much has been written about how the relationship between scientists and the media can shape the efficient transmission of scientific advances to the lay public (Cook, 2007; Bubela et al., 2009). Good science journalists are specialists in making complex topics accessible to a lay audience, while adhering to scientific accuracy. Unfortunately, pieces of science journalism can also oversimplify and generalize their subject material to the point that the basic information conveyed is obscured or at worst, blatantly wrong. The impact of a basic discovery on human health can be exaggerated so that the public thinks a miraculous cure is a few months to years away when in reality the significance of the study is more limited. Even though scientists play a part in transmitting information to journalists and ultimately the public, too often the blame for ineffective communication is placed on the side of the journalists. We believe that at least part of the problem lies upstream of the interaction between scientists and members of the media, and exists because i) we underestimate how difficult it is for scientists to communicate effectively with a diversity of audiences and ii) most scientists do not receive formal training in science communication.

Communication to a layperson audience is difficult

Collectively, we agree that scientists need to be good communicators, but communicating science to laypeople is not a trivial task (Racine et al., 2005; Illes et al., 2010; Keehner and Fischer, 2011). Scientific ideas can be complicated and communication of these ideas often becomes mired in discipline-specific jargon and terminology. However, there is often an assumption that because scientists are experts in their field and think clearly, they are also naturally experts at communicating science to laypeople and can communicate effectively (Radford, 2011). There are certainly notable neuroscientists, such as Oliver Sacks and Robert Sapolsky, who have made their work accessible to the public through popular science writing. However, we do not think that these and other scientists who are literary figures in their own right, including Carl Sagan, Stephen Hawking, E. O. Wilson, and others, should be presented as evidence of scientists' innate ability to communicate (Radford, 2011). These scientists have honed their communication skills over many years of practice and have sought opportunities for public discourse far beyond the extent of most researchers.

Developing skills to communicate science at a level that a general audience can understand requires deliberate practice and careful attention to language. For example, scientists are often criticized for failing to discern the difference between jargon and everyday language. Paradoxically, this can be a more different task for an expert in a field than a novice, because the expert is so far removed from the experience of encountering the term or concept for the first time. Professors face this problem in the classroom; while they are experts in scientific content, they may not be experts in what has been called pedagogical content knowledge, i.e., knowing what pedagogy will be most effective for beginners to learn the material (Gess-Newsome, 2002). In parallel, one problem for experts communicating neuroscience to non-scientists may be a lack of knowing effective ways to communicate with non-scientists. Neuroscientists may assume that words like "neuron" or "synapse" are common knowledge, when in fact the majority of the population may not have a working definition of these terms. Additionally, words such as "protein" have different meanings in everyday language (e.g., "protein" shakes) than in a biological context. The gaps between what scientists assume the general public knows and what the general public actually knows could be bridged by refining these communication skills in the training of scientists.

Most scientists do not receive formal training in science communication to the public

As scientists advance in their academic careers from undergraduate to graduate student to postdoc, they become more and more specialized in their chosen discipline or sub-discipline. These sub-disciplines are increasingly disparate, requiring scientists to become better communicators to forge collaborations between disciplines that may even start viewing each other as laypeople (Kennedy, 2007).

Although there are myriad opportunities for scientists to communicate their science to other scientists (e.g., courses with mock grant proposals as the main assignment, lab meetings, departmental retreats, and scientific conferences), there are few avenues for them to communicate, in written or oral format, to a lay audience. One of the few organizations dedicated to improving science communication to the general public is the Alan Alda Center for Communicating Science at Stony Brook University (http://www.centerforcommunicatingscience.org), which offers programs for masters and PhD students in scientific disciplines and a traveling workshop, in addition to internet-based opportunities for scientists to explain fundamental scientific concepts to the general public. The American Association for the Advancement of Science (AAAS) (http://communicatingscience.aaas.org) and the New York Academy of Science's Science and the City program also offer opportunities for scientists to engage with the public (http://www.nyas.org/WhatWeDo/SciencetheCity.aspx). Importantly, the aim of these programs is not to train future science journalists, but to provide communication skills to research scientists to enable them to better convey the details and impact of their work to the general public. Efforts and resources such as these constitute significant progress fostering a population of scientists with improved communication skills. However, these opportunities cater to a self-selecting group of scientists who must go out of their way to seek communication training.

At their home institutions, students sometimes have the chance to participate in informal science outreach, such as community events on campus, volunteering at a science museum, or hosting a tour of their laboratory. Neuroscientists may be most familiar with events such as Brain Awareness Week where they are encouraged to teach the public about brain-related topics, often through collaborations with local high schools and museums. However, these activities are relatively informal and infrequent, underutilized by trainees pursuing careers in a research discipline, under-recommended by mentors, and most importantly, most could not be considered formal *training* in science communication.

Despite the inclusion of science communication as a core competency for undergraduate biology majors (AAMC-HHMI, 2009; AAAS, 2011), few undergraduate or graduate science curricula offer coursework-based opportunities for students to practice this skill. We believe that integrating a requirement for communication of science to the general public into undergraduate and graduate curricula would promote the skills and confidence for future researchers to effectively communicate about their work with the general public, and importantly, would not detract from the scientific rigor of the training programs.

An analysis of the curricula of the top ten neuroscience programs in the United States according to the 2010 US News and World Report indicates that none require a course focused on science communication to a layperson audience. According to the descriptions of these curricula on the program websites, most students are required to take specialization courses in neuroscience, statistics, and ethics. Students are often required to practice their ability to communicate to other scientists at seminar series, departmental retreats, or journal clubs, indicating that science communication is seen as a valuable skill. However, there were no requirements for a science communication course to laypeople, either through coursework or more formalized opportunities. Stanford University and Johns Hopkins University offer elective courses in science communication to the public, which is an important first step but will only benefit a small subset of aspiring scientists. The lack of formal, integrated training in communication denotes a critical gap in the curriculum, especially as we strive to produce citizen scientists equipped to communicate effectively with the general public, as well as scientists in other disciplines.

Infusing science communication training into the curriculum: An example

Although there is still a need for widespread curriculum reform to incorporate explicit training (Chappell, 1998), there are a few examples of courses that provide formal training for aspiring scientists to become better communicators to a layperson audience. Here we present an example of one of these courses: a writing-intensive undergraduate and graduate neuroimmunology course that we developed and implemented through the Immunology Program in the School of Medicine at Stanford University. Although the course maintained a primary focus on mastery of basic scientific content, it also gave students the opportunity to develop skills to communicate science to a layperson audience. We believe that the unique format of the course afforded students the practice necessary to improve their communication skills, while remaining focused on scientific content.

Each week, students attended lectures on a current topic in neuroimmunology taught by an expert and read a recent primary scientific paper describing a critical advance in the field. The principal assignment in the course was the writing of a New York Times “Science Tuesday”-style article directed to a layperson audience summarizing the key aspects of the paper and the implication of the findings. To facilitate the writing process, students discussed the primary scientific paper with each other and with graduate student teaching assistants in a weekly discussion section. The students also received feedback on their article from the teaching assistants and had the opportunity to revise the assignment if needed. Students wrote five of these articles throughout the ten-week term, giving them extensive practice translating complicated scientific knowledge to a more accessible – and jargon-free – summary of the main points of the paper.

For a final assignment, students wrote a New York Times-style article on a broader topic of their choosing in neuroimmunology. We used peer feedback as a way to refine the writing. An additional layer of feedback and revision was a formalized mechanism that we developed for the students to seek and incorporate direct feedback from laypersons, specifically defined as people who have not taken college-level biology. Many students highlighted this exercise as one of their favorites of the class.

The goal of the course was not to train future science journalists; rather, our aim was to give future scientists and physicians a better grasp on science communication. According to surveys, students enrolled in the course primarily due to their interest in neuroimmunology and had plans to attend graduate school in biology or medical school, indicating that we attracted our target population.

Additionally, our intention was to promote proficiency rather than mastery. We understand that separate degrees can be awarded for science communication, so we do not propose that one 10-week course can be sufficient for mastery. Our objective was to provide an introduction that laid the foundation for students to become more aware of what it takes to communicate effectively with a non-scientist audience.

We have published a manuscript describing the impact of our neuroimmunology course on students’ perception and confidence of their communication skills (Brownell et al., 2013). Our study indicated that the course positively affected students’ self-confidence in communicating science to a layperson audience and also showed that students were more confident in their writing skills. Notably, student attitudes about the importance of communicating science to the general public were extremely positive, even in the pre-course surveys, indicating that our target population recognized the importance of science communication and was highly receptive to the opportunity to develop the skills necessary to become effective communicators. These results mirror other studies showing that most scientists are open to learning how to better communicate science to the public (Chappell, 1998; Hartz, 1997).

Recommendations for developing undergraduate and graduate courses highlighting science communication to the public

To facilitate the design of courses promoting the skills and experience we describe, we provide a set of guidelines for others who are considering designing courses that incorporate an emphasis on science communication with a layperson audience.

Teach communication in the context of basic science.
First, we recommend housing the course in a basic science program and teaching communication in parallel with basic science content. If our goal is to equip future scientists and physicians with a broad set of skills for life-long, effective science communication, we believe that upper-level undergraduate science courses should begin to incorporate formalized, layperson-directed communication exercises. Maintaining a focus on mastery of scientific content has the advantage of attracting a target population of future research scientists: students who are not necessarily predisposed to be interested in science communication and plan to pursue research or medical careers, not science journalism. The second advantage is that we feel students take a basic science course more seriously than an elective to fill a communication requirement. In our experience, science-major undergraduates and research graduate students were extremely receptive to the communication elements of the course, indicating in post-course surveys that the NYT-style article exercise provided an innovative approach to grapple with the content of the lectures and primary scientific literature.

Practice doesn’t make perfect, but does improve skills.
Second, we recommend that instructors incorporate ample

opportunities for practice and revision into the course. While some courses that focus on science communication have only 1-2 science communication assignments (Poronnik and Moni, 2006; Moni et al., 2007), we feel as though it was vital for our students to have multiple opportunities to build on their skills throughout the term. Written science communication to laypeople, much like any other writing, improves upon multiple opportunities for revision. We often saw that student writing would swing from one extreme to the other; students would write with too much jargon on their first assignment and then overcorrect in their next assignment, limiting jargon, but losing all scientific complexity. It would often take multiple assignments with the opportunity for several revisions for students to strike the right balance of explaining scientific concepts without using too much jargon. Furthermore, we believe that the improvements over multiple revisions we observed in student writing reflected an increased understanding and ability to interpret the primary literature and grasp complicated scientific concepts, central goals of many upper level biology courses.

Encourage real-world application of coursework to improve student motivation.

Third, we recommend that instructors try to find routes to give student coursework a real audience. In our course, we invited panels of science journalists and writers, who discussed strategies of effective communication with students and critiqued their work. A few students had the opportunity to develop written pieces for publication in such venues as the Multiple Sclerosis Discovery Forum, turning their classroom assignments into open-access articles that had real world application for communicating neuroscience (http://www.msdiscovery.org/news/essays_opinions/323-discriminatory-disease).

Another option is to publish a newsletter or class blog that could provide information to the public. This could be a way to have the class fulfill a service-learning niche, but perhaps more importantly, this will likely create greater accountability on the part of the student. Students can see that their work can have real and immediate impact. Interfacing with a lay audience is also a good way to check their assumptions of what an average layperson may know. For example, what counts as jargon? DNA? Neurotransmitter? Plasticity? Through direct interactions with laypeople, students can get a better sense of what concepts may be particularly challenging for the public.

Another option for giving student work an authentic outlet would be to partner with student publications that already exist on campuses. Perhaps an issue of a campus publication could be focused on student work from the course. An option appropriate for graduate students may be to partner with scientific journals to help translate complicated scientific information in recent publications to a layperson audience. Currently, the Journal of Neuroscience gives graduate students the opportunity to write reviews of recent articles for an audience of other graduate students; perhaps journals would be interested in expanding this practice to generate articles targeted to a general non-scientist audience.

Expand training to oral communication.

Finally, we encourage instructors to be creative in the ways that students can learn to communicate with a non-scientist audience. While it is important for scientists to be able to communicate via uncomplicated and effective writing, it is likely that they will have more opportunities to communicate orally with laypeople. Whether this involves speaking on a National Public Radio program such as *Science Friday* or at a large fundraising event, scientists need to be able to speak to a diverse audience who may be limited in scientific knowledge.

We focused our course primarily on written communication because i) we wanted to develop students' writing skills, ii) we used student writing as a proxy to assess their mastery of the scientific content of the course, and iii) we wanted to incorporate extensive draft and revision opportunities. However, the need for formal training of scientists to communicate orally to the lay public is equally important. One of us (S.B.) has developed another neuroscience course that emphasizes oral science communication and has included opportunities for students to improve in both their writing and speaking skills. In this course, the final assignment is a final paper directed to a non-scientist audience and also an oral presentation during which students explain their chosen topic in neuroscience to a panel of non-scientists. These non-scientists evaluate the speaker on the basis of how well they were able to understand the topic.

Other possible ways to incorporate oral communication include having students present their final paper topics to science classes at a local high school, or the organization of a public symposium at the end of the term. Providing students with an authentic communication experience serves the dual purpose of educating the public about a particular topic and ensuring that students take the assignments seriously.

Is it better to teach these skills to graduate students or undergraduates?

We have not differentiated between undergraduates and graduate students because we believe that both populations will benefit from formal scientific communication training. Our course was offered concurrently to graduate students and undergraduates. Surprisingly, we found that the undergraduates often produced work of higher quality than the graduate students. This could be due to undergraduates taking coursework more seriously than graduate students and spending more time on task. However, it could also be that teaching communication skills earlier in one's training has a larger benefit. Accordingly, we think that incorporating formal training in science communication to a layperson audience early on in science curricula will promote a culture of communication with the general public within scientific disciplines. Further, integrating formal training in science communication at the undergraduate stage will foster the idea that it is important to develop communication skills in parallel with scientific reasoning and research skills.

CONCLUSION

We encourage other academic communities committed to improving science communication to implement courses incorporating explicit training in communication of science to a general public audience as part of basic science curricula at the undergraduate and graduate level. As we have demonstrated with our neuroimmunology course, science communication skills need not be taught in stand-alone electives, but can be integrated effectively into lecture-based courses whose focus is analysis of primary scientific literature and mastery of scientific content.

It is not sufficient to rely on science journalism or the efforts of a rarified group of literary researchers to be responsible for the public understanding of science. We believe that formal training in science communication can promote the routine practice of scientists actively communicating about their work with a diversity of audiences, including the general public. Building communication skills is a difficult endeavor, involving limitation of discipline-specific jargon and active engagement with the target audience to determine their level of knowledge. However, these skills can be developed in parallel with scientific content knowledge and research training, hopefully with a synergistic impact on aspiring scientists.

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Address correspondence to: Dr. Lawrence Steinman, Department of Neurology and Neurological Sciences, Beckman B002, 279 Campus Drive, Stanford, CA 94305-5316. Fax: 650-725-0627, Email: Steinman@stanford.edu.