Using the Tools of Informal Science Education to Connect Science and the Public

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Traditional modes of communication within the scientific community, including presentation of data at conferences and in peer-reviewed publications, use technical jargon that limits public engagement. While altering word choice is an important method for increasing public engagement, the data itself may not be enough. For example, communicating the lack of evidence that vaccines cause autism did not convince many reluctant parents to vaccinate their kids (Nyhan, Reifler, Richey, Freed, Pediatrics 133:e835–e842, 2014). To address this gap between the scientific community and the public, many journals are adopting open-access policies and publishing lay-abstracts. Meanwhile, “meet a scientist” programs are creating opportunities for scientists to engage with the public in person. However, these programs may not be as effective as they could be. Many scientists still subscribe to an information-deficit model in which “the data speaks for itself.” Alternative tools that go beyond the data are needed. Here, I present three tools to create connections between the public and science: 3-D objects, games, and storytelling. These multidimensional and multisensory methods do more than promote understanding of scientific data; they may also be used to convey science as a verb and as an essential viewpoint in the human struggle for understanding.

INTRODUCTION

Publishing papers in peer-reviewed scientific journals and presenting data at scientific conferences are the traditional modes of communication within the scientific community. However, these do not communicate science effectively to the public due to their technical nature and use of field-specific jargon. Many scientists subscribe to the information-deficit model: if only the public understood x they would get y (1, 2). In the field of vaccination, for example, one argument based on the information-deficit model may be “if only the public understood the dangers of whooping cough, then they would vaccinate their kids” (3). However, this approach rarely works and often backfires, causing those presented with the information to hold more tightly to their opposing beliefs (4). Communication of scientific content alone is failing to connect with some communities; the once-fringe anti-vaccine movement has snowballed into a public health crisis (5). People perceive risks based on their cultural worldview (6), and scientists need to not just explain data but bridge cultural gaps. In the context of the anti-vaccination movement, the downward trend of vaccination rates may continue until these communities are engaged in a conversation about vaccines.

Scientists need educational tools to help them engage with the public, and their lack of familiarity with such tools may be a reason they don’t seek out outreach opportunities (7). Informal Science Education (ISE) institutions, including science museums, science centers, zoos, aquariums, planetariums, nature centers, and visitor centers of local, state, and national parks provide the opportunity for researchers to directly connect with the public. A growing body of evidence (reviewed in [8]) indicates that the public learns more science over their lifetime in an informal setting, like an ISE institution, than in a formal setting, like a classroom. The American Alliance of Museums reports about 850 million visits per year to American ISE institutions—more than the attendance for all major league sporting events and theme parks combined (9). This large visitorship suggests a public appetite for scientific content.

Interactions between the scientific community and the public in ISE institutions benefit all parties: (i) the public, who have the opportunity to learn more about the science of their daily lives; (ii) scientists, who have the opportunity to directly control the scientific message; and (iii) the ISE institutions, who, in providing the location of this exchange, confirm their cultural and societal importance to both the scientific community and the broader public. Some ISE institutions are experimenting with different formats for bringing scientists into the museum, including building “glass labs” where research is done in full view of the public (10, 11).
Many frameworks have been developed that outline features of effective and engaging content, including physical, sociocultural, and personal frameworks (12, 13); staging, physical layout, and social exchange frameworks (14); the 6P (place, purpose, person, people, process, and product) and partnership framework (15). From these educational frameworks and my work with the educators at the Smithsonian National Museum of Natural History (NMNH)—where I used my virology and immunology expertise to develop content related to infectious disease—I learned three concrete tools that could be used by the scientific community to translate scientific content and transcend the cultural gap.

**TOOLS**

**Tool 1: 3-D objects**

Object-based experiences in museums are long-appreciated tools for learning (16), particularly in object-based natural history museums and science centers (17, 18). Experiences with authentic objects are unique to the ISE setting and are extremely satisfying to visitors (17). New technologies have made physicalization of previously nonphysical data more accessible to ISE institutions as well as formalized educational settings and community organizations. These new technologies include 3-D printing or a 3-D–like environment created by virtual reality (19). The aim of physicalizing data is to provide an entry point for audience participation (20), particularly for nonspecialized audiences to interact with complex, sometimes abstract, concepts (21). Figure 1 shows the same concept—the transition of the proteins on the surface of the Respiratory Syncytial Virus from one shape to another—represented in two ways. Figure 1A is taken from a scientific publication (22) and is a graphical representation of the observed loss of antibody binding as proteins change shape. This graphic represents a classic mode of scientific communication: visualization of data. Figure 1B shows 3-D models, printed at the National Institute of Allergy and Infectious Diseases, of the viral particle with color-coded surface proteins, one color for each shape. From left to right, the different viral particles have different proportions of protein shapes. While these particular models have not been formally assessed for their ability to engage nonexpert audiences, they share traits with other learning objects that have: they are high in information density (23) and encourage learning-at-a-glance by nonspecialized audiences (24). Therefore, nonexpert audiences may linger at 3-D objects and learn more without interpretation than they would with other visual representations of data. The transition to presenting data in the form of physical objects is also happening within the scientific community, particularly as 3-D printing and virtual reality are opening new doors to explore atomic structures (25).

**Tool 2: Games**

Social interactions while learning content, “social learning,” can result in better long-term retention of scientific content in a formal (26) or informal educational context (27). Social learning fits well within ISE institutions because these are inherently social spaces where people from different backgrounds come together (28). Visitors come to ISE institutions expecting to learn or be entertained, but what they find satisfying are the experiences they share with one another (29).

In addition to promoting social learning, games offer the opportunity to highlight real problem-solving techniques which may increase learning and engagement (29). In Q?rius, the active learning zone for teens at NMNH, the game-based activity Outbreak: Phase 1 (Fig. 2) required the visitor to use contact tracing, a technique used by epidemiologists to

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**FIGURE 1.** Data versus 3-D object. A) Binding of antibody AM14 to Respiratory Syncytial Virus (RSV) surface proteins decreases over time as these proteins become inactivated and change shape. B) These 3-D printed models show proteins on the surface of RSV flipping from active (red) to inactive (blue) over time. These two figures illustrate the same concept but with different target audiences. Figure 1A is intended for a peer-reviewed scientific journal audience with field-specific previous knowledge (22). Figure 1B is more accessible to a nonspecialist audience both inside and outside the scientific community.
combat the Ebola crisis in West Africa in 2014 (30). The goal of this game was to get visitors to engage with the content by way of a problem-solving game. Quantitative (time to completion/disengagement) and qualitative (post-completion interviews and direct observations) metrics were used to develop this game. The self-guided nature of this activity meant that if it became overly complex or was not immediately interesting, the visitor would walk away. To keep visitors engaged, we asked them to solve an easier learning challenge first. A “win” early in the learning process satisfies the visitor and may serve to keep them engaged (29). Quantitatively, we found that the longer this activity took, the less engaged the visitor became. Through post-completion interviews, we discovered learning gaps that we later filled with clues that the visitor could access by choice. This cut down on the time that the visitor remained “stuck.” Through direct observation (illustrated in Fig. 2), we noted that this game, like many others, promoted intergenerational communication (31). Game-based social learning has also been successfully used by the Centers for Disease Control and Prevention (e.g., Solve the Outbreak, https://www.cdc.gov/mobile/applications/sto/web-app.html) and the American Museum of Natural History (e.g., Gutsy: The Gut Microbiome Card Game, www.amnh.org/explore/ ology/microbiology/gusty-the-gut-microbiome-card-game).

Tool 3: Storytelling

Narratives in formal education settings (32) and informal education settings (33) have been shown to be powerful tools for conveying scientific information. Narratives increase recall of the narrative storyline (34), and the increased recall carries over to scientific material presented alongside the narrative storyline (35).

Communications within the scientific community rarely convey personal narratives, and scientists become more practiced at using an objective and reductionist lens to communicate. A fundamental tenet of the scientific method is that science is reproducible and exists outside of the context of the observer; creating a narrative around the data seems to be at odds with this objective view (36, 37). Narratives appeal to the public because they increase comprehension, maintain interest, and are engaging in ways that are familiar from other mass media formats that expose the public to science (38). To build narratives into scientific communication without disrupting the objective point of view, I have found building narratives around the context of the data to be effective; this includes stories of discovery (14) and stories of human suffering (39).

In the infectious disease–based learning activity Outbreak, Phase 1 (Fig. 2), we sought to engage the visitor not only through a game, but also through connection with personal narratives. We asked the visitor to determine the path of illness spread by comparing the histories of six characters over 72 hours. Each “patient history” provided the character’s name, relationships (if any) to the other five characters, and a brief overview of the character’s locations and activities. In addition to providing information, these “patient histories” were brief narratives of people who were impacted by an infectious disease event. To increase the narratives’ potential for engaging the audience, we included details such as a photo, locations around the city that may be familiar to visitors, and syntax intended to resonate with experiences familiar to visitors. For example, from one of the activity descriptions: “Anna dragged herself to the Natural History Museum.” The intended result of fostering a connection between the visitor and the narrative was for visitors to connect the outbreak event, modeled on the 1918 influenza outbreak, to their own lives. To assess the impact these narratives had on the visitor, we conducted informal post-completion interviews. In these interviews, participants expressed surprise that influenza had such a quick and serious impact on the health of young people.

First-person narratives can help to make science personally relevant and can encourage people to invest in a topic (40). This can be achieved in numerous innovative ways and using different media, for example, comics (41), movies (42), plays (e.g., Climate Change Theatre Action 2017, www.climatechangetheatreaction.com/) and other art forms (reviewed in [43]).

SCIENTIFIC CULTURE

Engaging scientists in ISE institutions has been a highly effective way to train scientists on how to engage with the public (15). Indeed, successful programs exist at the Pacific Science Center (44) and the National Network for Ocean and Climate Change Interpretation (45). However, not all scientists have physical access to, time for, or awareness of
these programs. Here I have presented three concrete tools, derived from long-standing and foundational theories of informal science education, which could be used by scientists, researchers, educators, interpreters, and communicators to make scientific content engaging to the public.

By combining these three tools, scientists and others could create unique learning environments that make scientific content engaging and relevant. Outbreak: Phase I teaches concepts of infectivity, pathogenicity, and epidemiology using games and narratives. As a result, after completing the activity, people are able to relate these scientific concepts to their lived experience. Relating science to our everyday lives is a key piece missing in traditional science communication. For example, 88% of scientists say genetically modified (GM) foods are safe to eat compared with only 38% of the public (46). Although scientists still occupy a trusted space in the public sphere, this trust is eroding and depends on the political affiliation of the individual (47). One way to increase the trustworthiness of science is to be more transparent about science as a process, or verb (48). For example, here is a statement that presents science as a fact, or noun: “Genetically modified food is safe to eat.” This content can be revised to reflect science as a verb as follows: “Most food we eat today has been genetically modified through thousands of years of agricultural domestication that involves human-selected breeding. For example, today’s seedless watermelon looks very different from watermelons of the past (e.g., Giovanni Stanchi’s painting Watermelons, peaches, pears and other fruit in a landscape depicts watermelons in the seventeenth century; www.christies.com/lotfinder/paintings/giovanni-stanchi-watermelons-peaches-pears-a-5765893-details.aspx). New tools have been developed that allow us to directly edit the genome using molecular biology. Scientists and regulators are now researching how these new tools affect the growing pattern, nutrition, and availability of our food (49).” Science-as-noun is familiar from textbooks and is a collection of facts we are told to memorize and accept. However, science is a process used by scientists to understand the world.

**SUMMARY**

The popularity of museums testifies to the public appetite for information and ideas. The challenge is to meet and engage with the public where they are: in ISE institutions, in formal education settings (K–12 education, afterschool and enrichment programs, and college, undergraduate, and graduate programs) and in other educational contexts (lab tours, webcasts, take-your-child to work day). Some scientific publications are encouraging scientists to include both lay- and scientific-abstracts for publication, and open-access publications will also give the public greater access to science. Scientists themselves must be part of communication to the public, to ensure the depiction of science as a verb. Yet many scientists are given little training on how to communicate with the public. Institutions like the Alan Alda Center for Communicating Science (https://www.aldacenter.org) and the Center for Public Engagement with Science and Technology at the American Association for the Advancement of Science (https://www.aaas.org/pes) are trying to bridge that gap. In addition, the prevalence of citizen science projects and “meet a scientist” programs such as Skype a Scientist (https://www.skypeascientist.com) and Planting Science (https://www.plantingscience.org) are giving scientists opportunities to interact with the public directly. I have shared my experience as a scientist and educator in the hope that others may use these tools to create more connections between science and the public.

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