Translation and Dissemination of Health Services Research for Health Policy:

Key Insights from Museum Studies

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AcademyHealth is a leading national organization serving the fields of health services and policy research and the professionals who produce and use this important work. Together with our members, we offer programs and services that support the development and use of rigorous, relevant, and timely evidence to increase the quality, accessibility, and value of health care, to reduce disparities, and to improve health. Launched in 2013, AcademyHealth's Translation and Dissemination Institute helps move health services research into policy and practice more effectively. It undertakes activities that help research producers better understand the needs of research users, and serves as an incubator for new and innovative approaches to moving knowledge into action. This project is supported by the Robert Wood Johnson Foundation, Kaiser Permanente, and AcademyHealth.

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Executive Summary

Introduction

Academic researchers have traditionally seen the community of scholars as their primary audience and scholarly journals and conferences as their main mode of mass communication. The general public, however, can also be an important audience for scientists, and science museums are one type of institution where science communication takes place. Over time, science museums have transformed themselves from elite institutions focused on passive learning to engaging, community-driven organizations. Accordingly, they have developed best practices for effectively communicating complex concepts to nontechnical audiences. Their practices may offer lessons for those involved in communicating findings from other fields of study.

As part of the AcademyHealth Translation and Dissemination Institute's Lessons Project,[1] this paper highlights both established techniques and cutting-edge technologies used by museums to engage their audiences in learning experiences focused on current science. The paper also considers the application of the same techniques and technologies to the field of health services and policy research.

Key Findings

Museum curators have leveraged several approaches to engage their audiences in current science. These approaches offer lessons for science communication as related to individualized, social, authentic, and participatory experiences.

Personal and Relevant. The exhibit Expedition Health from the Denver Museum of Nature and Science demonstrates the importance of personalizing the learning experience for the target audience while establishing a safe and nonjudgmental environment. Visitors to the exhibit complete various health-related activities such as exploring their EKG, their wingspan versus height, and their pupil dilatation, all with the help of a visitor-selected avatar based on a real person who provides peer-to-peer learning throughout the experience. The inclusion of a nonthreatening peer in digital form and an emphasis on exploration of the changes in the human body rather than on clinical measurements allows relevant and personal topics to be addressed in a trusting and open environment.

Culture, Science and Society. The exhibit RACE: Are We So Different? reveals the important role played by museums in facilitating discussions of changing scientific understanding of topics ranging from biology to emerging technology. The exhibit, a partnership between the American Anthropological Society and the Science Museum of Minnesota, explores how the concept of human variation differs from race, when and why the idea of race was invented, and how race and racism affect everyday life. The exhibit discusses the role of science in the construction of the idea of race. Several of the

Image courtesy of Denver Museum of Nature and Science.

exhibit's components challenge visitors' beliefs about distinguishing people by race. The experience also pushes the boundaries of how museums engage with communities by leading facilitated discussions that encourage all participants to reflect on their experiences with race as a factor in their lives and communities. The exhibit illustrates the powerful impact that results when science is not presented in isolation but rather embedded within historical, societal, and personal narratives, allowing individuals to identify with the exhibit experience. By broaching the difficult concept of science's role in defining race, the museum becomes a neutral setting for the exploration of difficult topics.

Social and Group Activities. Museums can leverage the social nature of their institutions to encourage collaborative and learning in context.

- The Future Energy exhibit at the Museum of Science in Chicago illustrates approaches that help make a group learning experience successful through team building, collaboration, competition, and facilitation. The experience, which focuses on exploring basic energy principles, is divided into three sections: a preliminary exploration, an emotive film, and a series of interactive games played in small teams. Throughout the experience, facilitators guide visitors, monitor the energy of the participants, and help with interpretation.[2] The design team's thoughtfulness about aesthetics, the creation of team spirit, and the flow of interaction contributes to the exhibit's success.
- The Science Café is a model adopted by many museums to engage adult visitors in discussions with scientists about current research in casual settings. The informal discussions, organized by universities, museums, and professional scientific societies, bring together a wide range of participants and encourage "dynamic, two-way interactions between the scientist and the regular public."[3] The relaxed environment makes the scientific concepts accessible and encourages the public to learn about current research while allowing scientists to gain outside perspective on their work.

Future Energy visitors work in teams while aided by able facilitators. Image courtesy of JB Spector and the Museum of Science and Industry.

Dialogue and Decision-Making. Museums can facilitate experiences that guide visitors through a series of choices and help them consider biases or values important to them before making decisions on science-based topics.

- The Forums and Provocative Questions exhibition staged by the Museum of Science in Boston creates opportunities for dialogue and discussion of current science topics among visitors. The Forums are a series of facilitated discussions about questions that do not lend themselves to answers based solely on scientific evidence but that are also informed by personal experience and social values. Provocative Questions is an unfacilitated experience that encourages visitors to engage in dialogue around socio-scientific issues related to health and human biology.[4]
- The Marian Koshland Science Museum's Earth Lab uses an unfacilitated digital experience to support decision-making around the causes and impacts of global climate change. Visitors make a series of decisions aimed at reducing U.S. greenhouse gas emissions as they consider their own values related to the importance of topics such as energy costs, oil independence, and air quality.

Both examples balance scientific evidence with social elements and provide opportunities for visitors to make personal choices. The recognition that science is an integral but not an independent part of the decision-making process is critical to the success of the activities.

Visualizations. The Science On a Sphere® (SOS) system demonstrates the power of visualization techniques as a way to support understanding of complex processes and phenomena. SOS is a room-sized visualization system developed by the National Ocean and Atmosphere Administration (NOAA) that uses computers and video projectors to display animated data onto a six-foot-diameter sphere. SOS may be used as an educational tool to illustrate complex processes and changes such as atmosphere storms, climate change, and ocean temperature. Each site hosting an SOS system may compose its own "playlist" of data sets and simulations and enhance the experience with a facilitated presentation. Evaluations of the SOS system show that the visual experience supports a deeper understanding and more realistic portrayal of complex concepts.[5]

Often supplemented with facilitation, Science On a Sphere systems help public audiences visualize large earth systems. Image courtesy of the Space Foundation Discovery Center & Northrop Grumman Science Center

Participation in research and direct interaction with practicing researcher scientists. The experience of science museums also suggests best practices for facilitating constructivist learning experiences—situations in which individuals create their own understanding of the world by integrating new and existing knowledge. In the following examples, audiences interact with scientists and are in engaged in hands-on, participatory activities related to current science issues.

- The Portal to the Public (PoP) approach brings active researchers and other science professionals into museums to interact directly with visitors on their current research. As part of the model developed and tested by the Pacific Science Center in partnership with other museums, researchers undergo science communication training and interpretation workshops grounded in inquiry-based learning and led by museum educators. Researchers may then participate in face-to-face programs hosted by the museum, interacting with and engaging visitors in a variety of hands-on activities related to their research. Evaluation of the PoP approach has shown that audiences value the hands-on experiences, insights into the work of community scientists, and the ability of the scientists to communicate with the public.

- The Public Participation in Scientific Research model (PPSR) directly involves the public in the scientific investigation process, helping audiences both learn science content and experience the process of research through contributory, collaborative, or co-created projects. An analysis of PPSR models by Bonney et al. showed that involvement in a PPSR project helps participating individuals increase their awareness and knowledge of scientific concepts.[6]

Discussion

The examples presented in this paper illustrate the range of approaches taken by museums to communicate current science to general audiences. Despite the wide variety of settings and activities, similarities across the examples suggest five important lessons for science communication, including the communication of health services research findings:

Create an environment of trust. It is important to establish a trusting and open environment in order to help audiences understand and discuss uncertain or sensitive topics. Exhibits such as the RACE: Are We So Different? and Expedition Health demonstrate the value in creating a safe and nonjudgmental space for visitors to interact and engage in discussion about scientific topics.

Use trained facilitators. Many of the examples require thoughtful facilitation by museum staff or other science communicators in order to create and maintain an atmosphere conducive to learning. The Future Energy exhibit relies on a skilled facilitator to lead groups through the experience while Expedition Health uses a virtual guide to accompany visitors through the exhibit activities.

Ensure that information is relevant to the audience. Strong front-end audience research was one of the commonalities across the examples. It is also possible to establish relevance by bringing human stories or opportunities for personal reflection into the experience as in the RACE: Are We So different? exhibit and Forums experience.

Encourage dialogue. The examples demonstrate the value of engaging audiences in discussions about scientific topics as a means of facilitating learning experiences. Science Cafés, Portal to the Public, and Forums use different approaches to engaging visitors in conversation about scientific information. At the same time, these programs treat all perspectives as equal and provide opportunities for deliberation, using the trusted space and skilled communicators to good advantage.

Leverage partnerships. Finally, another commonality in many of the examples is the strategic use of partnerships. Leveraging the strengths of several institutions or individuals is often evident in successful examples such as RACE: Are We So Different?, Portal to the Public, and Science Cafés.

The examples in this paper illustrate how museums are exploring a growing number of approaches for presenting current science to audiences—from personalized digital experiences and advanced visual techniques to informal discussions and one-on-one interaction with scientists. The overarching lessons gleaned from these experiences offer useful tools for health services researchers and others interested in science communication.

Introduction

The transformation of science museums from elitist and insular cabinets of curiosity to more modern, community-driven places for hands-on learning holds many lessons for science communication. In this paper, we explore the best practices developed by museums to date to communicate information, ideas, and issues related to current science research. We have illustrated these approaches through a series of case studies from a wide variety of institutions. The experiences range from facilitated large-group discussions to open-ended exhibition explorations, but they all work at the intersection of science and society.

Science museums are unique physical spaces that bring together collections of historic objects or experiences. The earliest museums grew out of private cabinets of curiosity. At the time, opening the passive spectacle of natural history collections to the public was considered revolutionary. The educational approach embodied by the earliest science museums was based on the traditional unidirectional public understanding of science. The institutions often treated the visitor as a tabula rasa, a blank slate, which the curator could fill with the knowledge that he or she considered most worthy of public dissemination.

With their experiential approach to hands-on learning, science centers emerged in the 1960s in furtherance of Robert Oppenheimer's vision at the Exploratorium in San Francisco. In following the Exploratorium's model, the vast amount of science presented in contemporary science museums still tends to be organized around hands-on interactivity and active learning of basic scientific and technological principles. Today, the Association of Science and Technology Centers represents nearly 600 members across the country.[7] Contemporary science museum experiences are purposefully multimodal in order to appeal to intergenerational settings and to encourage social learning.[8]

How People Learn in Informal Settings

The National Research Council defines learning as "a progression with lifelong, life-wide and life-deep connections".[9] Life-long learning refers to the acquisition of competencies and attitudes by using information over the life course while life-wide learning refers to learning that is acquired as people move across a range of social settings and activities. Life-deep learning takes into account the range of belief ideologies and practices that influence individuals.[10] Abundant evidence indicates that people learn science outside the formal education system, through, for example, everyday experiences, programs, and designed settings such as science museums, zoos and aquaria, and nature centers.[11,12]

Though designed for learning opportunities, science museums are free-choice learning environments.[13] According to Falk, free-choice learning is "learning that occurs when the individual has control over what is learned, where it is learned and with whom learning occurs." Rather than depending on a prescribed curriculum, free-choice learning relies on the learner's agenda to determine the degree of learning. Accordingly, "free-choice learning can occur anywhere: art museum, zoo, science center, television and the Internet." Therefore, individuals enter free-choice settings such as science museums with their own sets of experiences, interests, curiosities, motivations, misconceptions, and understandings as well as with their own agenda such that they determine their level of engagement with exhibitions and displays. Each visitor constructs his or her own pattern of engagement and comes away with a uniquely personal experience. Each individual's motivation is intimately bound up with the individual's desire for satisfaction, identity, and well-being in the chosen place at any moment. People also visit science centers in various social group conformations and often seek experiences that are multigenerational and appeal to a wide swath of their group's interests.

Evaluations of the museum experience have shown that people have greater motivation to learn if the subject matter is directly relevant to their lives and interests and/or the learning process is interactive—one in which the learner can directly affect the learning process, content, and/or outcomes of the experience. Many museum exhibitions therefore tend to be materials-rich, inquiry-based, and open-ended—without a pre-determined correct answer. Given their unfacilitated nature, museum experiences need to be intuitive without reams of instruction. More and more, museum experiences strive to be social experiences, engaging two or more individuals in the group.[14] In addition, as mentioned in the paper in this series by Matthew Nisbet, framing the information to make it relevant to the target audience is important in order to increase the motivation to learn.[15]

Informal science education settings can provide learners with much more than an opportunity to increase their knowledge of a subject. The landmark study by Bell and colleagues, "Learning Science in Informal Environments: People, Places, and Pursuits",[16] proposed a "strands of science learning" framework that articulates science-specific capabilities supported by informal environments. The six interrelated aspects of science learning embodied by the strands describe how participants learn cognitively, socially, developmentally, and emotionally. In strand 1, learners in informal environments experience excitement, interest, and motivation to learn about phenomena in the natural and physical world. In strand 2, they generate, understand, remember, and use concepts, explanations, arguments, models, and facts related to science. In strand 3, participants manipulate, test, explore, predict, question, observe, and make sense of the natural and physical world. In strand 4, they reflect on science as a way of knowing; on processes, concepts, and institutions of science; and on their own process of learning about phenomena. In strand 5, they participate in scientific activities and learning practices with others, using scientific language and tools. Finally, in strand 6, they think about themselves as science learners and develop an identity as someone who knows about, uses, and sometimes contributes to science. The six strands deal not only with increasing knowledge and its application but also with attitude, efficacy, and self-identity. Museum experiences often focus on outcomes that go beyond the six strands.

As free-choice learning institutions, museums place a premium on strand 1, which can provide motivation for audience participation. The hands-on nature of many of the experiences in today's science centers often provides an opportunity for visitors to use strand 3. Given that most museums account for a significant visitorship from school groups, strand 2 often proves critical because it aligns closely with the focus of many content standards. The final three strands, while not as common in a typical exhibition experience, find application by science museums in some contexts. In any event, the six strands are not mutually exclusive, and a single experience may touch on several strands. For Bell et al., the strands provide a unifying resource from which to develop tools for practice and research, potentially playing a central role in refining assessments currently used to evaluate informal environments.

How Are Museum Experiences Studied?

There are limitations to what can be studied in a museum setting due to the fact it is a typically singular experience within a free-choice learning environment. In anecdotal interviews about museums, people often cite learning moments or emotionally moving moments that they enjoyed during their museum visits. However, given that museum visits are often short-term experiences, confounding factors make it difficult to track the long-term impact of patrons' visits. In addition, it is not possible to conduct randomized, controlled trials with museum visitors because the environment is a free-choice learning space. Nonetheless, museums are rigorous about setting outcomes or goals for their experiences and conducting evaluations at different stages of exhibition development and production.

Evaluation can provide insight into the conception of an experience, improve development of a new exhibition, and assess an exhibition's impact. Before launching a new exhibition, most museums develop a logic model that defines resources, target audiences, and short- and long-term outcomes. Museums conduct evaluations before (front-end), during (formative), and after the launch of a new product (remedial) and then again as the target audience experiences the product (summative). While front-end, formative, and remedial evaluations are essential for ensuring visitors' highest-quality experience, summative evaluation offers an opportunity to assess the degree to which the experience meets target outcomes.[17] Unlike science communication research, which is designed to explore a hypothesis, evaluation focuses on assessing product effectiveness. As such, it is particularly difficult to draw broad conclusions from the results of an evaluation. In addition, most evaluation results are not published in the peer-reviewed literature, although several websites, including informalscience.org and informalcommons.org, publish evaluations of selected projects.

Some of the case studies presented in this paper are new, and not all of them have undertaken a complete summative evaluation. In those cases, we focus on the design process.

Challenges and Opportunities for Museum Presentations of Contemporary Science

Traditionally, most science museums focused on communicating established science where the information consists of the results of completed studies whose implications for society are clear. In the late 1990s, Hyman Field, director of the National Science Foundation's Informal Science Education program, started the Public Understanding of Research (PUR) initiative. In Field's vision, PUR would focus on public education about current research; the social, ethical, and policy implications of new findings; and the importance of continued support for basic and applied research.[18] For Field, PUR provided an opportunity to present cutting-edge research while helping public audiences understand the process of scientific research. PUR set out to demonstrate that "research involves observations and trials, controls and correlations, repetitions and revisions, [and] would help individuals evaluate scientific claims and conclusions encountered in the course of daily life."[19]

For Field and other colleagues, the importance of educating the public about current science research was clear. They believed that public audiences were genuinely interested in science and technology yet had low levels of comfort with and knowledge of science topics ranging from emerging technologies, such as nanotechnology, to global processes such as climate change. In addition, it was obvious that the more emotionally charged the issue, the greater would be the need for an unbiased source of information. More than two decades ago, Field made the argument that the field of informal science education was uniquely poised to reach the public at all levels. He was convinced that those who most needed the information, i.e., those who make or will make decisions for themselves and their families, require access to accurate, up-to-date, unbiased, and substantive information on issues that occupy the public domain. And, given that every museum has a deeply rooted and unique connection to its community, the American Alliance of Museums (AAM) issued a call to action and asked how museum professionals can redefine the relationship between museum and community and allow communities to own museums. AAM posits that museums should function as resources and facilitators of dialogues that matter most to people. The following recommendation made by the National Research Council strengthens the position of the AAM: "Industry and federal agencies responsible for carrying out infrastructure projects, and science and technology museums should provide more opportunities for the non-technical public to become involved in decisions about technological developments".[20] The Technology for All Americans Project[21] and American Association for the Advancement of Science arrived at similar conclusions.

Even though the argument for presenting current science in science museums has taken hold in the community, the presentation of current topics involves inherent challenges. Durant articulated these challenges by contrasting the difference between presenting "finished" and "unfinished" science.[22] While traditional museum exhibitions are in development for years with a significant budget, an exhibition on current science requires rapid development at a low cost or must at least embody features that lend themselves to rapid updates at a low cost. In addition, unlike the case of conventional museum exhibitions that present a complete, unchanging, and clearly significant story, museum exhibitions on current science – must devise an approach for tracking and telling a story that may be complicated by partiality, doubt, and controversy. Over the past decade, museums have used the inherent qualities of current science to engage the public by assuming a journalistic approach, pulling the public into the research process, presenting various points of view, and demonstrating openness about information sources.

Since museums' first forays into presenting current science in the early 2000s, the institutions have expanded their modes of interaction with their audiences. The following case studies are intended not to highlight the content in science museums but rather to feature the approaches taken by museums to present current, often complex topics.

Lessons Learned about Communicating Current Science

Communication of current science does not abandon all the successful practices of decades past but instead takes into account the particular challenges of current science. The case studies demonstrate that museum exhibition and program developers have leveraged one or more of the following modes to engage their audiences with current science: individualized experiences, social experiences, authentic experiences, and participatory experiences. They have used established techniques as well as cutting-edge technology within the different modes.

Personal and Relevant

Current science may be presented in many contexts and at many scales—from global impacts down to the level of the local community. The following case study demonstrates how to make science accessible by ensuring that it is personal and relevant. Such an approach requires the conduct of robust front-end and formative evaluation to ensure that the personalization applies to the intended audience. As the case study illustrates, when dealing with personal matters, the environment must be safe and nonjudgmental if the target audience is not to be alienated.

Expedition Health—Denver Museum of Nature and Science, Denver, Colorado

Expedition Health is the newest iteration of the Denver Museum of Nature and Science's gallery focused on human health. The 10,000-square-foot experience is designed to be personal, dynamic, highly repeatable, appealing to all ages, and applicable to visitors' daily lives. The exhibition's learning goals focus on the dynamism of the human body and bodily changes that we can feel, see, and experience. Visitors entering the space receive a Peak Pass, which is a physical credit card with a unique barcode. Visitors then enter on the card their age, gender, and first name and select a buddy to accompany them through the experience. Based on a real person, the buddy is an avatar that provides peer-to-peer learning. The information on the card is referenced as visitors use the card to activate the displays. Throughout the gallery, the activities are accompanied by plastinated specimens that illustrate the related anatomy.[23]

The curators used their knowledge of visitors' reactions to the previous gallery to improve the experience in Expedition Health. The earlier exhibition was highly clinical, causing visitors to avoid certain activities out of fear of the results. Consequently, Expedition Health is intentionally nonjudgmental as it presents the marvel of the human body. For example, the earlier exhibition included an activity that measured blood pressure; in the new exhibition, the activity related to the circulatory system focuses on heart rate before and after exercise—a dynamic measurement that can change between visits. In addition, visitors may learn about, for example, wingspan versus height, wind chill, and pupil dilation, but not about their blood pressure, weight, or other measurements that might appear judgmental. The exhibition's approach avoids activities that either reveal negative information or address sensitive topics.[24]

The Denver Museum of Nature and Science focuses on dynamic processes such as the role of sunscreen in protecting skin from UV rays as a way to address personal aspects of health—without judgment. Image courtesy of Denver Museum of Nature and Science.

Central to the exhibition designers' approach was peer-to-peer learning. The designers wanted to avoid a dynamic of expert- to-novice instruction. To that end, the avatar buddies are the peers whose voices are heard in recordings of a diverse group of people from the Denver area. The museum selected the avatar buddies in a talent call and then required them to participate in a physical and intellectual boot camp that included an overnight hike in the mountains. During the boot camp, the avatars sat for interviews at various times; the unscripted interviews make up half of the exhibition's narration. For the rest of the script, the avatar buddies communicate various facts, such as "the heart is a muscle." When the curators originally conceptualized the avatar buddies, they expected that museum visitors would select people who shared their demographics. Instead, they found that certain avatar buddies were more popular than others. The most popular avatar buddy is an older man who could be described as grandfatherly. In contrast, the athletic 20-something avatar buddies are picked less often. It appears that visitors pick avatar buddies perceived as safe rather than buddies that might make them feel competitive.

Using several activities, the exhibition presents current science. One activity aims to raise awareness of the dangers of excessive UV exposure. Visitors enter their eye, hair, and skin color into their Peak Pass to determine the amount of sun exposure that they can tolerate before burning. Then, according to the day's forecast, they see how long they can remain outdoors in the sun near the museum and at the top of a nearby mountain. Summative evaluation has shown that the visitors make connections about the use of sunscreen on sunny days.[25]

The curators also conduct research in the museum amid the exhibition. The museum's initial experiment focused on the genetics of taste. Visitors learned that small genetic changes can have a profound phenotypic effect. The museum has completed data collection for the taste study and is about to launch a study on the impact of fat perception and satiety. Data collection in museums provides a visitor sample that is often more diverse in age and race than studies that pull from the population on university campuses. An institutional review board approves the research protocols, and visitors must provide informed consent before they participate in a study.[26]

The curators carefully considered how to handle the personalized data collected in the exhibition. To maintain a safe and nonjudgmental space, the curators ensure that the collected data remain anonymous and are retained for only a limited period, except in the case of the research on taste described above. In certain exhibitions, such as the wingspan and height station, the data from visitors are used in aggregated form, but not to compare individuals.

Visitors in social groups often travel through the exhibition together and share their results. The dynamic nature of most of the exhibition means that comparisons are less about competition and more about the marvel of the observed changes in the human body.[27] Visitors may access their data on the Web after their museum visit by using a number associated with a distinct barcode. The museum holds the data for three months.

In the Denver case study, the curators created a safe space by emphasizing peer learning, the careful and appropriate use of personal information, and excitement about the dynamic changes in the human body (rather than clinical measurements that might be indicative of health status). The designers also used several related lines of information to ensure their own understanding of the audience as well as the exhibition's relevance to visitors, including summative evaluation of the previous exhibition and results of the interviews with avatar "buddies." Personal topics can be sensitive, but trust, relevance, and openness can lead to successful communication.

Culture, Science, and Society

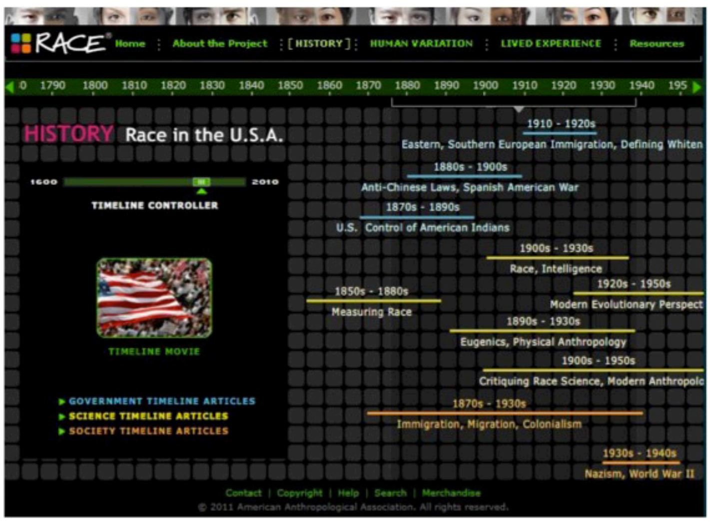
Science and technology have shaped modern society. Many of today's societal discussions are rooted in new scientific understanding and technological advances in topics ranging from biology to emerging technology.

RACE Exhibit—American Anthropological Society and Science Museum of Minnesota, St. Paul, Minnesota

RACE: Are We So Different is an exhibition developed in 2007 by the Science Museum of Minnesota (SMM) in cooperation with the American Anthropological Association. The exhibition describes how human variation differs from race, when and why the idea of race emerged, and how race and racism affect everyday life. The exhibition conveys three overall messages: race is a recent human invention; race is about culture, not about biology; and race and racism are embedded in institutions and everyday life (www.understandingrace.org/about/overview.html). Eric Jolly, SMM president, explains that "it's a science exhibition that promotes social justice by challenging visitors to think critically about what race is, as well as what it is not."[28]

The partnership between a prominent science museum and the preeminent social science/history association, combined with an advisory board that brought to bear many fields' most current thinking, was critical in establishing the exhibition's multidimensionality, accuracy, and relevance, leading to its successful tour to more than 50 sites across the United States (www.smm.org/travelingexhibits/race).

The exhibition's developers used a mix of interactive components, historical artifacts, iconic objects, photographs, multimedia presentations, and graphic displays to engage audiences with the subject matter. Building on vignettes with images, text, and video, the exhibition's history section demonstrates the role played by economics, popular culture, science, and politics in shaping our notion of race. Though race is not a biological concept, the exhibition acknowledges race's social and cultural reality as seen in the section on everyday lived experience where objects and multimedia experiences are used to explore housing practices, land ownership and wealth disparities, inequities in the health care system, and race and racism in our education systems. To help younger visitors relate to issues they experience in their daily lives, one video offers a glimpse inside the world of high school students as they talk about race, identity, and growing up in contemporary U.S. culture.



The image from the RACE exhibit shows how, over the last 150 years, the U.S. census categorized people according to skin color. Image courtesy of the American Anthropological Association.

It is important to note that the exhibition does not shy away from science's complicit role in the construction of the idea of race, with scientists attempting to classify humans into a taxonomic system on the basis of presumed biological and other differences. Not surprisingly, the exhibition uses several long-held misunderstandings about race as an opportunity to challenge perceived connections between race and biology. For example, the Sickle Cell Story clarifies that this commonly perceived "black" disease is related to malaria resistance. At the Science of Skin exhibit, visitors discover through an interactive demonstration involving use of a microscope that race is not a feature of our skin as they explore the evolution of skin color variation. At the Forensics exhibit, CSI fans hear from a forensic anthropologist about the challenges of using racial identification in detective work. Other interactive exhibitions challenge visitors' beliefs about distinguishing people by race. The Non-Concordance Sorting Game invites visitors to sort people according to traits that scientists historically used to distinguish one race from another. When the sorting categories fail, visitors learn about the inadequacies of outdated theories. A large World Map printed on the floor provides an interactive centerpiece for a cluster of components about human migration, gene flow, genetic drift, and the continuous distribution of human traits across the globe. In one key experience, Traveling Genes, visitors use a computer simulation to experiment with the dynamics of gene flow. The nearby Human Variation Video features scientists discussing what their research reveals about human variation and how it differs from common conceptions of race.

The exhibition also pushes the boundaries of how museums engage with their communities by drawing other voices into the race conversation through complementary program outreach. For example, the Science Museum of Minnesota used Talking Circles, which are discussions for groups of 20 or fewer participants based on Native American traditions in which all participants reflect on their experiences in learning about and experiencing race as a factor in their lives and communities. The facilitated discussions were designed for use with a range of audiences—business, community, government, and schools—and became a valuable, non-confrontational way to explore and foster diversity. The popularity of the Talking Circles exceeded expectations.

Many of the cities hosting the travelling exhibition have used it as an opportunity to engage new community partners and audiences. The exhibition's 2013 run at the Pacific Science Center in Seattle, a partnership with Seattle's Race and Social Justice Initiative, proved fruitful and resulted in the training of 200 facilitators who then led group discussions both before and after visitors made their way through the exhibition. The exhibition received significant local press coverage, generating greater awareness and broader attendance than originally expected.

Robert Garfinkle, project director of the RACE exhibit and director of the Science and Social Change Program at SMM, says, "Each Science Center's journey with its community is unique, but there is much we can learn from each other. SMM's experience with the RACE exhibit convinces us that the public is hungry for museums to help their communities tackle tough issues." Garfinkle believes that "science centers can be safe spaces to talk about social issues" and that "controversy isn't to be avoided, but instead embraced as a sign that we're on the pulse of issues that communities care most deeply about." He states that museums "can more fully bring the promise of science—thoughtful investigation, transparency of methods, the constant probing for truth—to bear on the issues that our society needs to address."[29]

The case study of the RACE exhibit illustrates the powerful impact that is created when science is not presented by itself but rather is embedded within historical, societal, and personal narratives.

The several entry points into science allow individuals to identify readily with the exhibition experience. In a significant step toward establishing trust, the RACE exhibit in particular acknowledged the mistakes made by and resultant repercussions in the name of science. The exhibition's engagement strategies succeeded by presenting the full story while positioning the museum as a place that strives to be a neutral setting for the exploration of difficult topics.

Social and Group Activities

Many of the topics at the intersection of current science and society require people to work together to address sensitive issues. The social nature of many museum experiences makes museums an ideal venue for generating collaboration. Visitors often come to museum exhibitions or programs with people they know. As they move through an exhibition, they may separate to explore on their own and then gather to share their experiences. At the same time, visitors who do not know one another may not be inclined to compare museum experiences. Yet, expert facilitation based on careful consideration of group dynamics and team building can help establish or build group cohesion. In addition to creating spaces for collaboration, museums are taking advantage of "third spaces" such as bars or festivals, tapping their dynamic social environments. The following two case studies examine, first, a newly launched exhibition that requires participants to work collaboratively and competitively and, second, a science café situated in a local pub where audiences discuss current science topics in a deliberately designed social setting.

Future Energy—MSI, Chicago, Illinois

Future Energy, a new experience developed by the Museum of Science and Industry in Chicago, illustrates some of the approaches that can make for a successful group experience. Hour-long exercises in team building, collaboration, competition, and facilitation can accommodate up to 30 people, which is a typical classroom size. Two staff members use different scripts depending on whether a group is a school field trip or random members of the general public.

The experience is divided into three parts: a preliminary exploration, an emotive film, and a series of interactive games played in small teams. Participants enter the initial space called the Energy Garden, which features stationary bicycles and hand cranks that trigger visual effects. The script emphasizes the message that energy is everywhere and that people can convert their own energy into different forms of energy. Visitors learn about basic energy principles. Teamwork and collaboration are required to activate many of the effects, which subtly demonstrate that people need to work together to make things happen. After six to nine minutes in the Energy Space, participants watch a short film that tells the story of Earth as the story of energy. In both the Energy Space and film, the designers purposefully chose aesthetically beautiful visuals in order to engage the audience and set a positive tone for the experience. Participants then break into small teams. Museum staff members try to keep family and social groups together, but strangers must often collaborate as a group. To help the groups work together, the facilitator runs an activity that requires participants to introduce themselves before moving to a game that involves playing with an energy ball (a small ping pong ball with two metal contact points on the outside that light up when a completed circuit is made).

The teams then rotate through five games: Future Power, Future House, Future Car, Future Neighborhood, and Future Transportation, which combine physical and digital interactive elements. The goals of the games are to improve energy efficiency and to learn how energy is generated from a variety of power sources. All teams have a chance to play all of the games. As with most museum-based games, the rules of the games are simple, permitting visitors to focus on content. Before the exhibition opened, it underwent extensive play testing, and it continues to be tweaked to ensure ease of use for people with a wide range of technological comfort. Throughout the experience, the facilitators guide visitors, monitor participants' energy level in order to ensure that they remain upbeat, and assist with interpretation.[30]

Future Energy visitors work in teams while aided by able facilitators. Image courtesy of J.B. Spector, Museum of Science and Industry.

The design team's thoughtfulness about aesthetics, team spirit, and the flow of interaction all contribute to Future Energy's success. Groups as diverse as middle school students on field trips and participants in business retreats have visited the exhibition, which offers great appeal not only because of its content but also because of the opportunities for team building.

Science Cafés

Science museums recognize that, while they are able to attract and retain family groups, they are less successful in engaging adult visitors, especially repeat visitors. In an effort to attract and retain adult patrons, some museums have adopted the science café model. Science cafés, also known by their original name—café scientifique—began in the United Kingdom as a grassroots public initiative that now operates in hundreds of locations in several countries (www.cafescientifique.org/). As described on the Science Café Website, "Science Cafés welcome people who may or may not typically get involved with scientific discussions. They are not exclusive club meetings for scientists and science majors, nor do they take place exclusively in lecture halls or science museums. Science Cafés can (and do) happen in informal community gathering spaces all over the world. The successful café fosters an informal atmosphere where all participants feel encouraged to participate. These are not long lectures with a passive audience listening to an expert. Rather, they are dynamic, two-way interactions between a scientist and the public. In this way, the public feels empowered to learn, and the scientist speaker gains valuable perspective on his or her own work" (www.sciencecafes.org/).

The success of the science café model lies in the informality of the venue and the lively interaction between scientists and attendees, fueled by food and beverage. Image courtesy of the Pacific Science Center.

Organized by universities, museums, professional scientific societies, or volunteers, science cafés make science accessible. Patrons enjoy themselves, relax, discuss issues, and enter or leave at will.

Experiences based on social behavior, whether in the context of a museum-based group activity or a social setting structured for a joint experience in science learning, purposefully capitalize on current understanding of human behavior and peer learning in social settings. Social interaction and collaboration are essential components of situated learning; that is, learners become involved in a "community of practice" that embodies certain beliefs and behaviors.

Dialogue and Decision-Making

Despite the adage "knowledge is power," the evidence from the field of science communication and decision research does not support the premise that providing additional information leads to informed decision-making. People often use mental shortcuts to make decisions that, in turn, may be subject to unconscious biases. To assist people with decision-making related to science-based topics, museums have developed a set of structured experiences that guide visitors through choices and help them consider their biases or values before making a decision.

Forums and Provocative Questions Exhibit, Museum of Science, Boston, Massachusetts

One of the Museum of Science's approaches to current science topics is to create opportunities for dialogue among citizens. As part of the Museum's larger Current Science and Technology initiative, staff members have conducted a series of Forums that bring together groups of participants for facilitated discussions about questions that do not lend themselves to answers based solely on scientific evidence but that are simultaneously informed by personal experience and social values. Such questions are often termed socio-scientific questions. Some of the museum's live facilitated Forum programs complement an unfacilitated exhibit called Provocative Questions, which encourages visitors to engage with each other in dialogue around socio-scientific issues related to health and human biology.[31]

The Forums may include up to 100 participants. One or more scientific experts introduce the topic with brief background talks. Participants then work in small teams on illustrative case studies. For example, during a recent Forum on whether mosquitoes should be genetically modified to help halt the spread of mosquito-borne illnesses, the teams worked through case studies focusing on malaria in Mombasa, Kenya; West Nile virus in Colorado; and dengue in Key West, Florida. In each case, participants considered the perspectives of different stakeholders. All of the teams then considered a case relevant to their local area. In the final step, the teams summarized their deliberations and presented their decisions about the issues at hand.

Forums bring together a cross-section of the general public to discuss science and societal issues. The findings from the Forums provide the basis for exhibitions. Image courtesy of the Boston Museum of Science.

Museum staff wanted to see if they could incorporate a version of the Forum dialogue experience into the museum's new Hall of Human Life, a gallery that focuses on how humans are changing in changing environments. The hall is divided into theme areas that represent five "environments" that change people: physical forces, living organisms, food, social communities, and time—all of which people alter in a variety of ways—sometimes without realizing it. Provocative Questions (PQ) is a section of the gallery that involves visitors in discussion and deliberation on how people decide to make changes in their environments. At any one time, PQ engages visitors in a single topic of discussion in several ways. The topics change every six months and, over time, represent questions drawn from all five environmental theme areas.

The PQ exhibit examines current societal issues that science can help explore but that also depend on other factors for resolution. Personal experiences and social values play important roles in the way we make decisions about provocative questions and how we talk to others about them. In fact, research on cognition and decision-making related to highly provocative topics has found that nonscientific factors often override scientific evidence, frequently leading to different interpretations of the same evidence. At any given time, the core of the PQ experience focuses on a specific topic that first undergoes testing in a live, facilitated Forum program; the results of the testing help determine the exhibition's content.

Using the current provocative question as a content focus, the exhibition introduces visitors to three types of decision-making supports (personal experience, social values, and scientific evidence). In addition, visitors may analyze a series of video statements to help them identify the three supports. The central Form Your Opinion activity takes place in pairs, with visitors guided through consideration of each type of support related to the question at hand. First, visitors reflect on their experience as related to the question and talk about that experience with their partner. They then consider expressions of social values that surfaced during the live Forums and that align with social values identified in social science research related to decision-making. Next, visitors select from a series of nine short statements drawn from scientific research articles related to the topic and choose the one that most influences their view. After each step, visitors discuss the activity with their partner. Only after the exercise does the exhibition ask visitors to come up with their own answers to the provocative question and to share their answer with each other. Visitors may examine data about how other visitors responded to the provocative question—who picked the same statements that they did and how they supported their answers.

The Museum of Science's Forum programs and Provocative Questions exhibit offer a useful exploration of the use of both facilitated and non-facilitated group decision-making activities. The focus on the balance between/among personal experience, social values, and scientific evidence helps structure the overall experience.

Koshland Science Museum's Earth Lab, Washington, D.C.

In 2011, the Marian Koshland Science Museum of the National Academy of Sciences developed an approach to decision support that was designed to be short and unfacilitated, thereby making it accessible to a large number of museum visitors. Many structured decision-making experiences take the form of face-to-face or group activities that require a facilitator to guide participants through what can be a complex process while keeping the discussion on track. Such decision-making experiences can often take hours or even days or more. At Koshland, both the need for facilitation services and the time requirements for decision-making experiences initially limited museum visitors' participation in decision-making activities. To make some of the best practices in decision science accessible to a wider audience, Koshland has partnered with decision scientist Joseph Arvai to develop an unfacilitated digital experience designed to take 15 minutes or less.

The decision table is the centerpiece of Earth Lab, a 1,500-square-foot exhibition focused on the causes and impacts of global climate change. When visitors sit down at the table, they learn that they will participate in an exercise to explore ways to reduce greenhouse gas emissions in the United States. The first screen asks participants to weigh selected personal values related to cost, oil independence, land use, and air quality. Once they are satisfied with their choices, participants move to the next screen, which presents a target level of U.S. greenhouse gas emissions in 2050 and a variety of approaches to reducing emissions. The goal is to achieve the emission target while not exceeding the emission levels that satisfy participants' personal values. Participants may implement approaches such as building efficiency, nuclear power, or carbon capture to varying degrees. Each change influences both greenhouse gas emissions and personal values. For example, nuclear power does not affect air quality, but it carries a high cost. At any point, visitors may view deeper information or a number of preset scenarios. Once visitors are satisfied with their selection, they may view several models that project the global rise of greenhouse gases and temperature based on their selections. They may email their decision to friends or family.

Decision tools may embody a point of view. For example, Earth Lab is premised on the need to lower man-made greenhouse gases in order to reduce projected temperature increases, but the lab must present a range of options in an unbiased fashion. The solutions presented to participants should be accurate, science-based choices. In the decision table, each solution is grounded in algorithms that are always available as background information for use by museum visitors. Ultimately, the designers did not include some options on the decision table, such as the value of job creation, because they

The Decision Table takes visitors through decision-making steps to help them think about their values and the science behind climate change. Image courtesy of the Marian Koshland Science Museum of the National Academy of Sciences.

could not construct a factual basis that met the approval of the committee of scientific experts who reviewed all of the supporting information for accuracy and completeness.

Initial evaluation of Earth Lab's decision table indicates that visitors spend an average of eight minutes with the table, which is a significant amount of time for an unfacilitated, free-choice museum experience. In interviews, participants reported that they understand that no single bullet will solve the problem of global climate change, but they recognize the existence of a range of possible solutions.[32]

Both the Museum of Science and Koshland case studies balance scientific evidence with social elements and provide opportunities for visitors to make choices. Critical to the success of the exhibition activities is the recognition that science, though an integral component in decision-making, is only one line of evidence in the decision-making process. In addition, both case studies demonstrate that the exhibitions do not channel participants toward a single answer but instead lay out a range of possibilities for consideration.

Visualizations

We are living in the era of big data. Our ability to collect, process, and analyze data has never been greater. Yet, the availability of reams of data does not automatically lead to clarity and reasoned decision-making. Visualizations, however, can help make sense of large data sets by integrating data into compelling visual stories. Museums have been using their curatorial expertise that was once limited to objects to consider a variety of modes for the presentation of less tangible information such as data. Visualizations offer great potential to support learning by overcoming some of the basic limitations of language-based instruction for abstract, metaphor-rich, and model-based concepts that are common in most of the natural sciences, including geometry and earth systems science. Visualizations can have a variety of positive impacts on learning by, for example, reducing the effort required to solve problems, supporting the construction of mental models, and animating dynamic concepts.

CASE STUDY: Science On a Sphere

Science On a Sphere® (SOS) is a room-sized visualization system that uses computers and video projectors to display animated data on a six-foot-diameter sphere, analogous to a giant animated globe. Researchers at the National Oceanic and Atmospheric Administration (NOAA) developed Science On a Sphere® as an educational tool to help illustrate earth system science to people of all ages. Animated images of atmospheric storms, climate change, and ocean temperatures may be shown on the sphere, which is used to explain complex environmental processes in a way that is simultaneously intuitive and captivating. SOS has been installed in more than 100 locations worldwide, mostly in informal learning environments. More than 400 data sets and simulations developed by NOAA, NASA, museums, and other organizations have been created around the categories of atmosphere, ocean, land, and astronomy and are freely available on the NOAA Website.

Each site hosting an SOS system may compose its own playlist, culling from a library of data visualizations; in addition, each system may augment the visual experience with a facilitated presentation (sos.noaa.gov/What_is_SOS/about.html).

An example of a visualization created for SOS is Blue Planet, a seven-minute, narrated movie produced for the traveling exhibition WATER: H2O = Life (sos.noa.gov/videos/blue_planet_audio.mov). The Science Museum of Minnesota produced the movie for SOS in collaboration with the American Museum of Natural History and the NASA Goddard Space Flight Center. The movie provides an overview of how water shapes our planet and nearly every aspect of our lives. Using data sets from a variety of sources, including NOAA and NASA, it presents water as the driver of Earth's dynamic systems, the source of all life on the planet. It underscores just how rare and precious is Earth's water resource. The movie combines water-cycle and ocean current animations with real weather data sets.

Recognizing that the SOS is an innovative way to visualize data, 16 SOS sites implemented an evaluation plan to set a baseline for outcomes.[33] The evaluation showed that visitors absorbed new information and that the sphere enhanced the understanding of complex processes and phenomena. Visitors felt that the presentation of information on the sphere was realistic and that facilitation correlated with learning.

Often supplemented with facilitation, Science On a Sphere systems help public audiences visualize large earth systems. Image courtesy of the Space Foundation Discovery Center & Northrop Grumman Science Center

Visualization techniques are particularly useful when conveying information that includes temporal or spatial change. While effective on their own, visualizations may be greatly enhanced by interactions with a skilled interpreter.

Participation in Research and Direct Interaction with Practicing Research Scientists

A constructivist museum provides an environment in which individuals construct their knowledge of the world through the integration of existing and new conceptions, making personal sense of what they learn. The following case studies examine some of the best practices related to creating authentic experiences whereby audiences engage in activities whose learning outcomes include an understanding of the process of scientific research. Constructivist experiences may take the form of hands-on, problem-solving activities related to real-world issues; social activities that include conversation with experts; and participatory activities related to data collection for researchers.

Face-to-Face with Scientists

Increasingly, researchers and research organizations are being called on to engage with the public as a way to communicate current science. When external experts (active researchers and other science-based professionals) interact directly with museum visitors in the context of the museum, they help bring life to current science research while creating visitor experiences on a diversity of scientific topics. Field-wide research shows that gatherings of community scientists and public audiences in one-on-one or small-group interactions can transform the public's notion of "what a scientist is" by demystifying or humanizing the scientist, who is often seen as stereotypically inaccessible.[34] The Science and Engineering Indicators Studies and other studies have shown year after year that public audiences continue to place a high degree of trust in scientists.[35]

The Portal to the Public (PoP) approach is based on direct interaction between a community's active researchers and museum visitors. The Pacific Science Center developed and tested the model in partnership with Explora (Albuquerque, New Mexico), the North Museum (Lancaster, Pennsylvania), and the Institute for Learning Innovation (Annapolis, Maryland). In this approach, researchers participate in science communication and interpretation workshops grounded in inquiry-based learning before engaging with museum visitors. Experienced museum educators deliver the workshops, which focus on ideas in constructivist theories and visitor identity and motivation. During the workshops, scientists reflect on their own informal learning experiences and identify specific qualities that made those experiences memorable, thereby helping to ensure similarly meaningful experiences for visitors. Scientists observe and participate in hands-on, tabletop activities as models of effective engagement. They also use questions as a strategy to facilitate inquiry-rich learning experiences in order to support learners in making their own discoveries.[36] The Portal to the Public approach has expanded beyond its core partners and has found application in more than 30 science museums across the United States (popnet.pacificsciencecenter.org).

Scientists engage in hands-on, materials-rich learning activities grounded in informal learning at Portal to the Public science communication workshops. Image courtesy of the Pacific Science Center.

One example of a typical Portal to the Public event is Scientist Spotlight at the Pacific Science Center. The event takes place on weekends and targets general museum goers (family groups and individuals). It features three to 15 local scientists from a range of disciplines and offers hands-on, materials-based activities based on the scientists' research. Scientist Spotlight takes place in a gallery that features festive banners separating the space into nooks where individual scientists gather with small groups of visitors. Visitors interact with each scientist in a relaxed, intimate space, sometimes spending up to 40 minutes at each table. The open-ended, conversational nature of Scientist Spotlight allows scientists to tailor their content to their immediate audience, whether a 5-year-old child, an adult with limited understanding of the area of research, or an industry peer. A typical comment from a scientist underscores the fluid nature of the events: "I was able to have high-quality discussions with many visitors. I was pleased that I was able to have a variety of different kinds of conversations, based on the ages and interests of visitors. It was also rewarding that many of the conversations were quite long (20 minutes); that was a nice bonus of it being a quiet day at the museum that allowed the conversations to cover a lot of ground and follow whatever questions/tangents/curiosity the kids wanted to discuss."[37]

Research and evaluation of Portal to the Public programs such as Scientist Spotlight show that audiences valued the programs for their hands-on experiences and insight into the work of scientists in the community. The programs gave audiences an appreciation for science, its relevance, and its mechanics and showcased scientists as role models. Audiences were highly satisfied with scientists' ability to involve museum visitors, communicate about science, and interact with visitors. The programs demystified the stereotype of scientists and reflected the breadth of ages, ethnicities, and gender represented within the science community.[38]

Museums that highlight science researchers—whether or not researchers have participated in science communication training—make great efforts to promote programs that offer visitors the opportunity to meet and talk with "real" scientists. In fact, they market such events as special programs. The personal and conversation-based interaction with research scientists allows museum visitors to explore current science by building on their personal involvement with science.

Public Participation in Scientific Research

The past two decades have seen the development of several programs that directly involve the public in the process of scientific investigation. These programs help public audiences learn science content and experience the research process. Programs offer activities organized around citizen science, volunteer monitoring, and participatory action research, all of which fall under the broad category of public participation in scientific research (PPSR).[39]

According to Bonney et al., PPSR models differ from one another chiefly in the degree to which they involve the public and in the amount of control that the scientists maintain over their research.[40] PPSR projects may be broadly categorized as (1) contributory projects, which are generally designed by scientists and to which members of the public primarily contribute data; (2) collaborative projects, which are generally designed by scientists and to which members of the public contribute data but also may help refine the project design, analyze data, or disseminate findings; and (3) co-created projects, which are designed by scientists and members of the public in tandem and in which at least some of the public participants are actively involved in most or all steps of the scientific process.[41]

Although PPSR projects vary in the degree of collaboration between science researchers and volunteers, volunteers in most projects receive some degree of training in project procedures to ensure consistency in data collection and accuracy in data analysis. Current projects cover wide-ranging scientific content, from monitoring local aquatic invasive species to mapping the corners of the universe. Projects may engage a handful of participants in a small watershed to hundreds of thousands of observers spread across several continents.

One example of a PPSR project is the Audubon Society's Christmas Bird Count (CBC) (birds.audubon.org/christmas-bird-count). Every year, from mid-December to early January, tens of thousands of hobbyists fan out across North America and, together, do their best to answer two basic questions: How many birds are there? And what types? While the data constitute simple counts, the information is scientifically invaluable and contributes to conservation efforts. The CBC data set now covers 109 years, and the nearly 11 decades of data combined with a geographic range that spans the continent enable scientists to address questions that would otherwise be nearly impossible to answer. In the past few years, scientists have used the CBC data set to track the emergence and impact of West Nile virus, to understand the ecological effects of competition between introduced species, and to measure the shift that birds make toward the poles in response to global warming.

While PPSR projects have limitations for many types of scientific research, they may prove to be essential to others, particularly when data collection depends critically on a widespread network of observers. PPSR projects may play an important role in detecting global climate change as characterized by shifts in weather patterns, movements in the ranges of species, and large-scale transformations of ecosystems. An analysis of 10 PPSR projects by Bonney et al. showed that "PPSR projects contribute to awareness, knowledge, and/or understanding of key scientific concepts related to the study at hand," with understanding ranging from purely scientific information to environmental issues and regulations. The researchers found that PPSR projects are particularly expedient in engaging people with varying levels of expertise. According to Bonney et al., the "projects are excellent for developing science-related skills. Participants in most projects increase their ability to identify organisms, to use measurement instruments, to collect field data following specific protocols, and to sample consistently over time." The fact that information collected by citizen scientists has yielded some of the largest databases on the distribution and abundance of plants and animals on our planet demonstrates the importance of volunteers in gathering information that can help further the cause of science and environmental management.[42]

Discussion

We have collected a diverse set of case studies illustrating the range of approaches taken by museums to present current science. A look across the examples points to similarities that recur despite the diversity of settings or goals associated with a given activity. The first similarity relates to established places of trust. Museums engender high levels of trust and are neutral places for the presentation of scientific information. The second similarity relates to skilled facilitators or science communicators. Such individuals may be either members of an organization's professional staff or volunteers who undergo training in communication. Science communicators may even be "virtual" communicators as in Expedition Health. The third similarity relates to the relevance of information to target audiences as determined by solid front-end audience research and as evidenced in all the case studies. It is also possible to ensure relevance by bringing into the museum experience human stories or opportunities for personal reflection. The fourth similarity relates to opportunities for dialogue between two or more individuals by taking advantage of museums as neutral spaces and tapping the skills of trained science communicators. The last similarity relates to the strategic use of partnerships. Leveraging the strengths of several institutions or individuals is often a characteristic of the more successful case studies. One notable illustration of a successful, long-term partnership is the Nanoscale Informal Science Education Network, which has been producing and disseminating information about nanotechnology for over a decade.[43]

Most of the case studies focused on typical museum-going audiences. However, the RACE exhibit, Talking Circles, and Science Cafés are exceptions that reach wider audiences. When targeting underserved, hard-to-reach, and otherwise vulnerable populations, museums may need to make additional efforts to develop trust by, for example, seeking out target populations on their own turf and identifying a member of the community who is willing to serve as a bridge. Partnerships with already established and trusted organizations can help make introductions to and forge connections with the target community, launching much-needed dialogue.

In conclusion, museums are exploring a growing number of approaches to presenting current science. Many of the general principles may be applied to communication about health services and health policy research.

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