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Commentary: Roles, opportunities, and challenges—science museums engaging the public in emerging science and technology

David Chittenden

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Abstract Even a cursory reading of the public engagement in science (PES) literature over the past decade reveals that public engagement is becoming part of the "orthodoxy of 21st century science policy" (Stilgoe, Nanodialogues: experiments in public engagement with science, 2007, p 16), Moving forward, there appears to be strong consensus that (1) public engagement is an essential component for shaping sound science policies, research agendas, and governance structures; (2) more opportunities for accessible and successful PES need to be developed and implemented to have meaningful impact; and (3) a broader and more diverse range of publics need to be reached through PES activities. This article explores the role that U.S. science museums and centers could play in creating and delivering PES programming focusing on current science and technology developments and issues, with particular attention to nanoscience and nanotechnology. Also addressed will be some of the factors that support increased PES involvement by museums, some of the challenges museums need to overcome to sustain ongoing PES, and several recommendations to achieve broader PES impact through science museum participation.

D. Chittenden (✉)
Science Museum of Minnesota, St. Paul, MN, USA
e-mail: davec1230@gmail.com

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It is widely acknowledged that European institutions have driven the development of many of the successful initial models for public engagement in science (PES). These models include the first consensus conferences in Denmark in 1989, the first scientific café in the UK in 1998, the Science museum's revolutionary Dana Centre in London that opened in 2003, and the new visitor oriented Darwin Centre at London's Natural History Museum's, which opened in 2009. In Europe, there is clearly a vigorous governmental pursuit of involving the public in "upstream" discussions and deliberations with scientists and policymakers around critical science and technology issues. Accordingly, there has been considerable attention paid to public engagement with the developing field of nanotechnology, in both Europe and the United States, and that nanotechnology is providing a fertile field for advancing the ways to involve the public earlier in the emergence of a new and encompassing science and technology.

The U.S. Informal Science Education (ISE) Enterprise (including science museums, science centers, aquariums, botanical gardens, nature centers, zoos, and planetariums) represents a potentially vast national infrastructure that can bring strong institutional

capacities, educational expertise, and community-wide impact to support increased public engagement in current and emerging science such as nanotechnology. While ISE encompasses a large array of educational institutions, this article will focus primarily on science museums and centers, which make up the most robust and largest subset within ISE. Forty-five years ago, there were fewer than two dozen science museums and centers in the entire United States. Today, there are close to 500 science museums and science centers across the country and over 2,000 worldwide. Collectively, close to 80 million visitors stream through U.S. science museums annually (Association of Science-Technology Centers, http://www.astc.org). This explosive growth and the accumulated experience gained over the past four decades have resulted in a powerful public education enterprise that is arguably better positioned to deliver PES in the communities than any other comparable venue. According to Mayfield, "Science museums could become the live interfaces between contemporary research and the public, something no other medium can provide" (2004, p 112).

The core focus of science museums and centers is engaging the public in science learning. This is not a secondary or tertiary focus, but the prime focus. As a professional field, science museums and centers are highly skilled at science communication and translating complex science and technology issues in accessible ways that the general public can relate to and understand. Museums consistently reach a larger public audience than most other educational institutions and do so through innovative multi-modal learning experiences, including participatory exhibits, media and web-based programs, and staff and visitor interactions ranging from large-scale science demonstrations to one-on-one dialogs. Science museums are conveners and community gathering places, and some are creating successful educational forums and events that bring scientists, civic leaders, policy-makers, and the general public together in a neutral setting for shared learning. In the relatively short history of science museums and centers, they have become welcoming and highly trusted by the public to deliver accessible, unbiased, and participatory science learning experiences. Collectively, science museums and centers constitute an impressive, though loosely knit, national infrastructure that has the potential, if given the proper support, to lead the development of a robust and ongoing PES effort across the country.

Yet, despite these positive attributes and impressive growth, the current reality is that most science museums and centers in the United States are largely absent when it comes to being substantively involved in public engagement in current and emerging science. At the 2008 Association of Science-Technology Center (ASTC) National Conference, in the session titled "Why Don't they Understand? Public Perception of Controversy in Science," Arthur Caplan, a nationally known bioethicist and Director of the Center of Bioethics at the University of Pennsylvania in Philadelphia, criticized the assembled science museum community for what he considered their irrelevance and inattentiveness with respect to the important work of engaging the public in current science issues and in addressing the critical science-based controversies, especially social and ethical implications, of the time. Caplan's criticism pointed out what has been a lamentable reticence of the broader community of science museums and centers to pursue substantive PES in their communities. It is a fact that the great majority of science museums and centers present "known" science and its well established core concepts and principles, rather than "unfinished" science and new research. From my perspective as a science museum educator and administrator for the past 32 years, to understand why more science museums and science centers have not attempted to do more serious public engagement around current science issues is to appreciate the chronic challenges and institutional realities that science museums and centers face.

While many science museums represent almost ideal institutional settings for PES events and activities, relatively few science museums engage their audiences consistently in PES programs because such programs are neither viewed as central to their mission nor to their business and audience model. Most science museums and centers are focusing their programmatic efforts on introducing and engaging their audiences in science exhibits focusing on well-established science phenomena and principles and not on the emerging edges of science or its associated societal and ethical implications. Current science exhibits require constant updating that can be prohibitively expensive and staff-intensive. They also require a level of science expertise beyond the level

that many science museums and centers have on their staff. Another reality is that PES programs require extensive staff effort to plan and conduct and, because attendance is often limited, they cost more per participant than standard programs. PES programs are also often viewed as "outliers" as compared to the normal set of programs many museums offer. A clue to why this is so emerges if one examines a cross section of science museum missions and general descriptions. In reading such statements, one finds an abundance of words and terms that focus on "science discovery," "learning fun," "exploration," "entertainment," and "hands-on"; but few terms such as "science policy," "societal implications," "current research," or "civic participation" appear. Several years ago, the Science Museum of Minnesota (SMM) changed its mission statement from "Inviting learners of all ages to experience their changing world through science" to "Turn on the science: realizing the potential of policymakers, educators, and individuals to achieve full civic and economic participation in the world." SMM's inclusion of policymakers and educators as core audiences on which to focus surprised, if not startled, other professionals within the science museum community. To pursue as a mission how science engagement is linked to full civic and economic participation is a significant departure from the common science entertainment and discovery-oriented mission statements more characteristic of science museums and science centers. Science museums have the opportunity to become the "science hub" of their communities (Mayfield 2004, p 115) by taking on the more serious role of bringing together the public, scientists, and policymakers to explore contemporary science topics that have research and policy connections to local issues.

Another complicating factor science museums often face when striving to undertake greater PES programming is the fragility of their operating or business model. With increasingly fewer museums receiving any significant public support from local or state sources, the need for museums to earn a higher percentage of their annual budgets is growing. A number of leading science museums are highly dependent on admission and earned revenues to balance their annual operating budgets. When 80–90 percent of an institution's annual operating budget needs to be earned each year through admission revenues and associated sales, it inhibits the range and type of programs and exhibits museums can comfortably undertake. Many museum operating models depend on significant gate revenues from "blockbuster" exhibits that are highly popular with the general public. Major traveling exhibits, such as the hugely successful "Body Worlds" and "King Tut," are luminaries within this operating model. To a great degree, admissions-driven museums are increasingly trapped in a perpetual cycle of scheduling these expensive, but high revenue yielding blockbuster exhibits in order to keep their doors open. Such an operating model provides little flexibility and support for offering more PES programs that typically garner lower attendance and have higher participant costs. In museums facing these realities, marketing needs and budget realities often trump current science engagement aspirations. There is little doubt that without a sympathetic mission, dedicated leadership, and a supportive operating model that can underwrite PES endeavors, it becomes difficult, if not impossible, to initiate and sustain these efforts institutionally. As articulated by Mayfield:

> As our colleagues in marketing departments understandably remind us, what sells museum tickets in large numbers are exhibits not on recondite scientific research, but on tried and trusted popular themes, such as dinosaurs, sports, and space travel. It is this aversion to taking risks with our audiences' tastes, born of the precarious finances of most science museums, that makes it so difficult for contemporary research to get a foothold in science museum exhibits (2004, p 112).

Science museums and centers are clearly evolving and maturing in the range and complexity of the programs and exhibits they offer their communities, but moving from the classic identity and program centers of science fun and entertainment to more serious explorations of current science will require rethinking institutional priorities, operational models, and community service aspirations.

The net result of this state of affairs is that PES remains relatively rare in the typical program portfolio of most science museums and centers. It is not a part of the museums' ongoing and continuous program array. When museums move into this arena

with more intentionality and resources, what is also needed is a stronger connection to the policy making systems and apparati in the community. Most science museums are neither tied to nor involved with the formal science policy infrastructure within their communities or states, which tends to diminish the significance of any of the efforts of the museums' PES programs and their outcomes. When science museums move seriously into the PES arena, they need to find ways to become invited to and be given a seat at or near the policymakers' table.

In addition to mission and operating model challenges, it is also widely acknowledged that many science museums have simply little institutional experience with or willingness to take on science controversy. Many museums view becoming more active in presenting scientific controversies and effectively engaging the public as difficult and complicated. Ironically, visitor research has consistently revealed that "visitors enjoy engaging with controversy and think it is something that museums should cover" (Mazda 2004, p 129). Science museums that are transitioning their exhibits and programs to address contemporary and sometimes contentious science topics are increasingly places more "concerned with displaying science in the making, rather than science already done, and displaying the courage to show the messy uncertainties and ambiguities of emerging science" (Meyer 2009, p 5).

An example of a successful and self-sustaining program focusing exclusively on engaging the public in dialog around the "hot" topics of science is The Dana Centre at London's Museum of Science. This working laboratory for science dialog between scientists and the public uses a creative mix of program formats to generate discussion, including "puppet shows about genetically modified foods, talk shows, pub quizzes about science, as well as debates open to the general public" (Meyer 2009, p 5). The Dana Centre is helping museums rethink the relationship between science and society and providing ways and forums for the public to engage and debate with science and scientists. It represents a movement within some leading science museums away from a public understanding of science mode and toward a public understanding of research mode. Unfortunately, the success of the Dana Centre has not translated into similar programs at other science museums. While it is innovative and has demonstrated almost a decade of sustainability, this model has not been successfully imported into other existing science museums.

What is also clear when identifying challenges and barriers to greater PES among science museums is the reality that there is no consistent funding widely available to sustain a PES effort. According to Martin et al., "Having adequate resources allows museums to be able to take more risks in using new formats and presenting current research" (Martin et al. 2004, p 189). Those museums that point to rich programmatic efforts are buttressed by temporary grants or staff-dependent inter-institutional relationships that often disappear when personnel changes occur. There is little internal infrastructure in many museums to conduct and sustain PES. There is no permanent ligature between museums and research universities or institutions to co-develop PES programming. This is not a system around which a public engagement strategy can be built. It is a system that is ephemeral and unpredictable. It is also a system that cannot be duplicated based on the success of one institution, because of the idiosyncratic nature of the specific project, the community, or the institutions involved. This is a fundamental problem that needs to be addressed if there is to be any general advancement by the larger community of museums in the PES arena.

While these challenges are likely to persist within the science museum community, there are a number of positive external factors and forces building momentum that could support museums in strengthening their efforts to collectively make a greater contribution to the public's ongoing involvement and input in the critical science and technology issues of the day.

First, the informal science education field recently produced a seminal report that describes a conceptual PES model for what PES is and how it could be structured within the context of ISE. The Center for the Advancement of Informal Science Education (CAISE), housed within the Association of Science Technology Centers in Washington DC, published a report in 2009 titled, "Many Experts, Many Audiences: Public Engagement with Science." The report provides an excellent conceptual model and example strategies and methods for how ISE organizations can "provide opportunities for public awareness of and participation in science and technology" (CAISE 2009, p 11). This foundational study comes at an

opportune time for informal science education institutions. While historically there has been moderate interest, discussion, and program experimentation around PES, there was a lack of a consensus around what constituted PES and how the ISE field could play a more consistent and meaningful role in this endeavor. The traditional role of many science museums focused on communicating core science principles and ideas to the public and on involving the public in hands-on learning to better understand the science in everyday life. Science learning in museums is most often unidirectional in that the public is gaining appreciation of and knowledge from the presentation of science concepts and ideas through various programs and exhibits. The CAISE report distinguishes this type of generic engagement with public engagement with science. Rather than a one-way communication of knowledge from science experts to the public, PES has a specific meaning that is characterized by mutual learning shared by the lay public and the scientists. In this type of PES, "everyone who participates develops new or more nuanced understandings of issues and opportunities" (CAISE 2009, p 9). As noted in the report, such public contributions are often not reflective of the public's scientific or technical knowledge, but rather on the public's wisdom and knowledge drawn from their life experiences, buttressed by their personal and community values. A critical distinction being made in the CAISE report is that PES, at its most effective, involves dialog and active participation by both the public and scientists and that each benefits from listening and learning from one another. This mutual learning approach assumes that both the public and the scientific community have important knowledge and perspectives to contribute to the development of science and how and in what ways it is applied in society. As stated in the CAISE report:

> PES in ISE seeks to bring together those who generate scientific knowledge, those who affect its use, and those who, perhaps unknowingly, experience it in daily life to discuss the social, cultural, and ethical aspects of science. In this way, PES in ISE moves beyond serving as a means for transmission of scientific knowledge or an acceptance of scientific authority. Instead, PES activities serve as platforms for discussion and negotiating knowledge to understand issues and make decisions. As such, the learning that occurs in PES is expected to be a complex process of scientific, social, cultural, and ethical understanding, which may result in changes in attitude about and understanding of science, the topic of interest, and one's role in society. (CAISE 2009, p 23).

The sense of equity and balance between participating stakeholders is a critical element of this model. According to the CAISE report, "Public engagement strives for 'creating legitimacy and a sense of shared responsibility by involving the public and diverse stakeholders early and often in a change process, rather than after decisions have been made" (2009, pp 1–2). The principles of "mutual learning" and "mutual respect" seem to be fundamental to the higher order PES activities that have been developed in both Europe and the United States.

A second positive factor supporting increased PES is the educational opportunity that the emergence of nanotechnology in the public consciousness has created. Nanotechnology, as a broadly multidisciplinary field with almost unprecedented potential and global impact, is providing a fertile content field for U.S. science museums to mobilize a stronger PES presence. In "Nanodialogs: Experiments in Public Engagement with Science," Jack Stilgoe (2007) observes that the most important and innovative nanotechnology developments are likely years off, but that the hype surrounding nanotechnology provides a significant opportunity for there to be innovative PES activities that "raise questions at an earlier stage—to encourage a 'frontlash' more than a backlash," (p 13) and to move more from the usual focus of PES as a exercise in "risk" assessment, mitigating public concerns, or attempting to build "legitimacy" for the science and its applications. Stigloe argues that nanotechnology is still sufficiently upstream for there to be a more robust and vital PES that focuses not on fears, but hopes, and not about regulation, but innovation. He states, "If public engagement is worth doing, it is worth doing with constructive ends in mind," and, further, that PES in this vein "might help us to shape innovation trajectories, strengthen the public value of technologies, and open up new spaces for political leadership" (Stilgoe 2007, p 19). Stigloe further infers that

"rather than simply becoming the Next Controversy, could nano become an arena in which relationships between science, innovation and democracy are redesigned?" (Stilgoe 2007, p 7). Stigloe raises intriguing questions that could stimulate new PES initiatives that explore public and scientist perceptions around a broader range of topics and issues.

Certainly, Stigloe undeniably lays out a challenge and an opportunity for organizations that aspire to provide PES for their audiences and communities. While the PES efforts in Europe have historically outpaced and out-innovated similar efforts in the United States, greater interest in PES from American governmental agencies, informal science education institutions, funding entities, and scientific and technical societies are beginning to create more momentum for U.S. PES activities. In 2005, the National Science Foundation (NSF) made the largest single award to informal science education institutions in its history. Twenty million dollars over 5 years was made available to a core set of science museums through a 5-year cooperative agreement to develop and implement the Nanoscale Informal Science Education Network (NISE NET). Most recently, this summer NISE NET institutions were awarded an additional 5 years of funding from NSF. The NISE NET project "supports a variety of activities designed to build the capacity of informal science institutions and research organizations to work together, and to engage the public in learning about nanoscale science, engineering, and technology" (NISE NET, http://www.nisenet.org). Embedded in the general description of the NISE NET efforts is the unmistakable language and pursuit of PES:

> The promise of nanoscale science is that it will dramatically improve our lives, bringing great advances in applications as diverse as medicine, energy, electrical and chemical engineering, and materials. At the same time, nanotechnology's potential negative impacts also touch on a broad range of societal concerns—environmental pollution, toxicity, the prospects of artificial life, and privacy violations. There is a middle ground between scientific boosterism and extreme rejection of these new technologies. Open deliberation can help steer the public conversation toward this more thoughtful, considered middle ground" (NISE NET, http://www.nisenet.org).

Part of the program agenda for NISE NET during its first 5 years has been the development of a series of public forums that enabled the public to discuss and deliberate with one another and with nanoscientists the societal and ethical implications of nanoscience research and its potential applications. A core team of five science museums from across the county created and tested a forum model, selected forum topics and associated materials that could be shared with the broader ISE field, with the intent to build the capacity of ISE to conduct PES programming in their home communities. Based on an extensive summative evaluation, the forum model that was developed and the three tested topics within that model proved successful across all participating museums. Participant understanding of nanotechnology was increased, especially by those who did not express overly strong interest in science prior to the forum. What also resulted was that participants increased their confidence in being able to communicate to others their ideas and viewpoints about nanotechnology and their sense of the risks and benefits associated with different applications of nanotechnology. Another major benefit reported from participants in these forums was listening to and learning about the diverse perspectives and ideas participants had about the social, ethical, and economic implications of nanotechnology (Flagg and Knight-Williams 2008, p v).

As of 2010, several hundred science museums and other ISE organizations have participated in NISE NET training workshops, presented NISE NET exhibits and programs, conducted forums, or participated in the national Nanodays science event. There is little doubt that the NISE NET project has expanded impressively throughout the country's science museums and science centers. In the next 5 years (2010–2015), if NISE NET continues to invest in innovative programming and partnership strategies, it could solidify the most impressive, best coordinated, and productive museum-based network pursuing PES that the informal science education industry has ever launched.

A third positive factor that is driving greater PES efforts is the NSF's initiation of its Broader Impact criterion. Broader impact in the lexicon of NSF supports, if not requires, research project awardees to

provide public education outreach around its scientific work. This Broader Impact mandate has stimulated stronger, mutually beneficial programming partnerships between research institutions and ISE organizations. C. Alpert from NISE NET and the Museum of Science in Boston has written extensively about these burgeoning partnerships and how the program development and community outreach expertise of science museums and centers can assist research institutions to achieve their "broader impact" requirement at the same time gaining greater visibility and connection to their local communities (Alpert 2009). In addition, science museums are increasingly partnering with NSF funded National Research Centers for multi-year public outreach components that include PES activities. A good example of this substantive partnership is the Science Museum of Minnesota's collaboration with the University of Minnesota's National Center for Earth Surface Dynamics (see http://www.nced.umn.edu/). No longer are science museums and centers strangers to the network of National Research Centers and major research universities of the country. Beyond its Broader Impact mandate, the NSF has begun to make longer term funding opportunities available to the science museum field that significantly extends the normal 3 or 4 year grant cycle. Having longer term funding of 5 to 10 years, as was awarded to the NISE NET museums, enables institutional partnerships to be established and resulting program networks and relationships to grow and strengthen.

These positive forces and other developments are aligning in ways that should support a stronger PES effort and program platform coming out of the ISE field. However, to better secure a strong and resilient PES effort across a larger set of museums, especially small to medium-sized institutions, will require more robust experimentation and innovation in terms of PES program models and formats. New experimental models need to be developed and implemented by science museums and centers, especially when resources are available to undertake such experimentation. NISE NET provided seed money from 2005 to 2010 to a team of five museums to develop forum programs around nanotechnology and its implications. What did result was a well-tested, thoroughly evaluated, and relatively simple forum model that could be widely replicated across the ISE field (NISE NET 2009). There emerged more enthusiasm among the five partner museums to converge on one distinct forum model and to create a forum "toolkit" for supporting the museum field. There was less enthusiasm to diverge on multiple forum approaches that might have yielded a greater range of ways to engage the public in discussion and deliberation around science issues. This is not to criticize the NISE NET effort, because what was produced was highly successful, useful, and instructive for the field. Yet, the opportunity remains for a more intentional and diverse development of experimental approaches and models for conducting PES in museums. Given the funding horizon and the fact that the NISE NET project is well seeded across the country, museums have the opportunity to take more intriguing programmatic risks with grant resources and to move beyond the standard and comfortable ways science museums have typically engaged the public in current science topics. Models such as Science Cafes or science lectures/debates with question answer sessions are part of the trusted and true repertoire of many science museums. These will remain on the programmatic menu of museums into the future. More innovation, however, is needed. At the Science Museum of Minnesota, we have made a greater effort to diversify the ways the visiting public could on any given day engage in current science. Recent opportunities have ranged across the following visitor experiences and include:

- Taking part in a public forum on nanotechnology and the environment that engaged participants in discussion around potential benefits, costs, and policy issues that could impact them and their community.
- Visiting the exhibit "Race-Are We So Different?" that explored biological, cultural, and historical perspectives on human variation, and then participated in a facilitated "talking circle" with other visitors to reflect and share their views on race.
- Seeing a live theatre presentation on the pros and cons of advanced medical applications using nanotechnology followed by an audience Q&A and discussion.
- Sharing views and reacting to the blog contributions of other visitors on stem cell research through the museum's web-based resource, Science Buzz (http://www.sciencebuzz.org).

These learning experiences are all designed to engage visitors in current science and research issues of the day, to provide opportunities to learn some

science, and perhaps most importantly, to support a sharing of their views, values, and opinions about these issues and topics. At the Science Museum of Minnesota, a recently funded project, "Brighter Futures, Public Deliberation About the Science of Early Childhood Development," will employ small group conversations, citizen conferences, public programs, a highly interactive 1,600 sq. foot exhibit, and two research studies to engage museum visitors, policymakers, and caregivers in deliberation abound the latest early childhood development research with the goal of influencing the improvement of related public policy.

What is encouraging about public engagement efforts such as the Brighter Futures Project is an emerging shared agenda-setting between the scientific community, the community of museums, and participating publics. The values, perspectives, issue frames, and constructivist knowledge that the public brings to a deliberative and dialogic activity can contribute as much to the successful outcomes of the event as can the contributions of the scientific experts. Societal and ethical perspectives viewed through the prism of public values and community sensibilities are essential elements of PES, and museums can lead the way in helping create the PES formats that insure such inputs and elements are present.

As an educational enterprise, science museums need to begin using the full range of PES program/activity options from traditional forums and town hall meetings to new and more innovative approaches integrating multi-format, multi-media, web-based program options. A more robust and consistent museum-based PES effort offers the positive prospect of strengthening the linkage and communication between the concerned public and the broader scientific research and policymaking community. For PES to truly become the new "orthodoxy of 21st century science policy" (Stilgoe 2007, p 16) will require legitimizing public input and enabling that input to have authentic impact on the fundamental policy directions and oversight mechanisms of science and technology. While science museums are beginning to take on a larger role and leadership in the creation and conduct of public forums and activities to help convey such public input, more consistent effort in this area needs to happen. Supporting and encouraging science museums to be more courageous, intentional, and creative in involving the public in voicing their perspectives, concerns, and issues around science and technology developments will benefit not only the institutions, but will strengthen the communities and the diverse audiences we serve.

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