

A Guide to Building Partnerships Between **Science Museums** and University-Based **Research Centers**



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Abridged Version
for the NISE Network

About This Guide

This printed edition is partially derived from *Small Steps, Big Impact: An Online Guide for Museum Leaders Developing Education Outreach Partnerships with University-Based Research Centers*, first published in 2010 at: www.risepartnerguide.org. This 2013 edition has been revised, updated, abridged, and adapted for use by both university-based researchers and science museum planners. The online version can be consulted for additional information and resources. This printed edition was produced for distribution through the Nanoscale Informal Science Education Network. **The partnership development strategies apply to education outreach collaborations in all areas of current science and technology research.**



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why?

Working together, science museums and university-based researchers can inspire and broaden participation in our contemporary voyage of discovery and innovation.



Science museum and research center partnerships...

- Inspire young people
- Enhance science and technology literacy
- Celebrate science and engineering innovation
- Foster community discourse on new technologies
- Bring resources, energy, and timeliness to STEM education

SMALL STEPS, BIG IMPACT...

Many science museums already collaborate with university-based researchers. Researchers may serve as board members or volunteers, advisors for exhibits and programs, speakers and science café participants. The organizations may join forces for special events like Earth Day or NanoDays. These are all terrific starting points for developing deeper and longer-term collaborative efforts. The goal of this guide is to assist in that process.

1. PROLOGUE

Two Physicists Walk into a Science Museum...

We had just launched the Museum of Science's new Current Science & Technology Center in 2001, when two Harvard physicists walked in, sat down in my office, and suggested we arrange an education outreach collaboration that could be included in their proposal to the National Science Foundation for a new nanotechnology research center. Professors Robert Westervelt and Bertrand Halperin weren't quite sure exactly what to recommend, but they knew they wanted to help the public understand what was then a very new field, and they had ideas about sending leading researchers over to give talks to Museum audiences.

Anyone with experience in a science museum can tell you that such an offer is an iffy proposition. Very few research scientists have the knack or the training to be able to engage general audiences, and relatively few individuals will volunteer to spend their evening or weekend time attending a lecture. Museums are "free-choice" or "informal" learning environments. They depend, like television, on catching and hooking audience attention, striving to engage hearts, minds, and even hands. While "formal" learning environments like schools have attendance records, exams, and grades to reinforce learning, science museums rely on the promise of fun, wonder, and discovery.

Cautiously, I probed my distinguished visitors – was there going to be a budget to support the collaboration? Would they be amenable to suggestions for other sorts of activities for introducing nanotechnology to our audiences? Could they imagine applying some of the funding to the creation of more interactive museum experiences? Could they see the value of supporting members of our professional staff to work with their research teams to create these experiences? Bob and Bert were not only open to such suggestions; they were enthusiastic. They invited me to be a Co-PI, and welcomed the Museum of Science (MOS) as one of the marquee partners on the proposal. It was submitted to NSF including a large sub-award for the Museum.

Over the next eleven years, the Harvard-MIT-UCSB-MOS Nanoscale Science and Engineering Center reached hundreds of thousands of people with museum programs and exhibits, face-to-face guest researcher events, New England Cable News television stories, iTunes podcasts, *The Amazing Nano Brothers Juggling Show*, the *NanoNerds* YouTube Channel, several *Nanotech Symposia for Educators and Journalists*, the *Talking Nano 6-DVD Set*, science communication workshops for early career researchers, and forums on

societal implications of nanotechnology. The collaboration was enthusiastically endorsed by the NSF panel in charge of deciding renewal funding for the research center, and it helped to spawn the idea for the Nanoscale Informal Science Education Network, a consortium of science museum and research center collaborations.

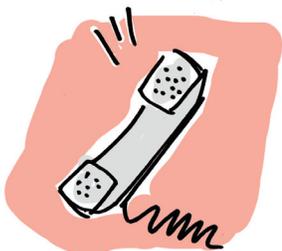
The model Bob Westervelt and Bert Halperin helped create in 2001 was expanded three years later, when Professors Ahmed Busnaina and Jacqueline Isaacs of Northeastern University, and Joey Mead and Carol Barry of the University of Massachusetts-Lowell, invited the Museum to join as an outreach partner in their new NSF Center for High-rate Nanomanufacturing, now into its ninth year.

These community-aware faculty reached out to the Museum in pursuit of the broadest possible educational impact for the state and federal investments in their centers of research and innovation. Well in advance of submitting their proposals, they called to confer on plans and budgets. Unfortunately, it doesn't always happen this way.

Last-Minute Phone Call

*Hello. My name is Professor _____. I'm calling from the ____ department at _____ University. I was just hoping to get in touch with you **today** regarding this very large grant proposal that we're putting together and actually submitting **by the end of the day...** and one thing that was suggested and that would be great would be if we could establish some links with the Museum. If you can give me a call back..."*

- Voicemail left on author's phone



Many science museum directors get last-minute phone calls like this one from researchers about to submit a proposal to a federal or state funding agency. They suggest the science museum might host a set of lectures or perhaps an exhibit to be designed by their graduate students in connection with their proposed research. Typically, the university caller needs, rather soon, a letter of support on museum letterhead, expressing commitment and enthusiasm for the proposal; and typically, with few questions asked, the museum representative will fax over a letter in time to meet the deadline.

But where does this leave the partners? It leaves them without an evidence-backed education and outreach plan, and without a reasonable budget to

support one. Savvy grant review panels will doubt the existence of a serious commitment or strategy. Even if the research goes on to receive funding, neither partner will have much incentive to follow through on the vaguely-stated intent, especially in the midst of other more pressing priorities. This type of situation tends to produce only token efforts, perhaps in time for critical grant reporting periods. What has been lost? A great opportunity to benefit both the research enterprise and the broader community. But it doesn't have to be this way.

A Meeting of the Minds

This is a guide for constructing *successful* research center – science museum collaborations, as described earlier in the Prologue, rather than ones produced through chaotic last-minute arrangements. A successful collaboration doesn't need to be grand in scale. What counts most is that the collaborators discuss the options in advance, find the right fit for their respective interests, resources, and prospective audiences, and then agree on a plan of action and on an appropriate budget.

Let's start out by identifying and commenting on some common misperceptions that can be stumbling blocks for a "meeting of the minds" on science museum and research center collaborations.

Sometimes heard on the science museum side:

- **Researchers are usually interested in education and outreach only when it can help them win grant funding for their research.**

Yes and no. Grant-funding requirements like the National Science Foundation's "Broader Impacts Criteria" certainly help catalyze efforts by university researchers to engage in education and outreach, but most researchers believe in the goals of education and outreach and genuinely want to share their enthusiasm for their work. The effort can seem daunting, however, if they don't feel confident about their own skills to connect to broader audiences. This is one reason why researchers can find it so helpful to team up with science museums.

- **There is no funding to support education outreach collaborations.**

Not true. Some direct informal science education grant opportunities encourage such collaborations. And sub-awards to science museums through university research center grants can also provide significant support, without the additional burden of competing against science education organizations nationwide. These large research center efforts

involve teams of researchers sharing multi-year, multi-million dollar awards, and they are often expected to include education and outreach programs. Grants to individual researchers may provide only a few thousand dollars for education and outreach, yet even a small amount can accomplish much.

- **They call at the last minute, so there's no time to plan or budget appropriately.**

Yes, as we've seen, this does happen. Science museum managers are learning to just say 'no, thank you' to these last-minute invitations, in order to discourage the practice. They don't wish to perpetuate a culture of nonchalance toward the education and outreach mandate and its vital importance for our society.

- **Most scientists don't know how to connect to our audiences.**

Some will, some won't. Some scientists are terrific with public audiences and with young people, and their face-to-face presence in a science museum can electrify a crowd. Others may be less comfortable. It's the job of the museum liaison to understand the difference and to work with researchers where their contributions can best be deployed - either in front of an audience or behind the scenes. And, by the way, most scientists and Ph.D. candidates are receptive to advice and coaching on engaging broader audiences. They realize the tremendous benefits and rewards these skills can bring.

Sometimes heard on the university side:

- **The science museum already has plenty of funding and staff available to undertake new projects and new topic areas.**

In fact, science museums are mostly non-profit education institutions that rely for their survival on ticket sales, government grants, donations, corporate sponsorships, individual bequests, and memberships, as well as a sprinkling of parking fees, food concessions, and function rentals. Operating budgets are tightly allocated and staff time is fully spoken for. New exhibits, programs, and special events require advance planning, and must fit within various ongoing programming priorities.

- **Museum audiences are child-centered and entertainment-centered, so they need to keep focused on the basic ideas of science, rather than exploring cutting edge research.**

Not the whole story. Science museums around the world are being revitalized as marketplaces for new ideas in science and technology, and as forums for engaging members of their communities in exploring potential impacts on our society.

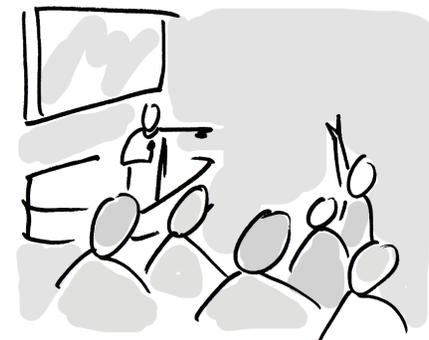
- **My graduate students can build a new exhibit for them.**

Not likely. The conception, design, and production of most science museum exhibits is highly professionalized, and guided by rigorous education, design, accessibility, and safety standards. This requires sustained team commitments to planning, prototyping, evaluation, and construction. However, with a little help from their science museum colleagues, grad students can gain new skills in communication and outreach with public audiences, and they can take these with them wherever they go.

- **The science museum serves best as a lecture hall for researchers to deliver findings to broader audiences**

Lectures and talks have their place in science museums. Even so, most university-style talks and powerpoint presentations need considerable transformation before they are ready for prime-time. These audiences need to hear the Why? and What for? before the How and the What. They prefer relevance rather than procedural detail; illustrations rather than bullet points; and stories rather than jargon. Demonstrations and hands-on experiences will be more than welcome, as will opportunities for discussion. Collaboration with museum staff should help researchers craft these more welcoming and rewarding communication experiences.

If well-planned, partnerships between science museums and university-based research centers provide win-win outcomes for everyone, including the intended audiences, and, they can be lots of fun. Chapter Two provides guidance for science museum managers on how to lay the groundwork for building successful collaborations.



2. LAYING THE GROUNDWORK AT SCIENCE MUSEUMS

Partnerships with university-based research centers can enliven museum exhibit halls with the enthusiasm of youthful researchers from diverse backgrounds. They can bring audiences an exciting flow of new discoveries and innovations. They can provide new resources, funding, and scientific expertise. They can strengthen community ties and enhance K-12 and teacher professional development programs. They can even help advance the research efforts of their university partners.

Without careful planning and stewardship, however, partnerships can sometimes lead museums astray from institutional goals and priorities, stretching limited resources. Therefore, museum organizations would do well to conduct a proactive strategic assessment of their needs and goals. This will better prepare them to recruit partners with complementary goals and resources, and to respond appropriately to external offers of collaboration.



A careful strategic assessment should do at least two things for your organization:



Identify high priority subject, program, and resource areas that will benefit from collaboration with university-based researchers.



Provide a “to-do” list of infrastructure items that will need to be put in place to manage partnerships, as well as to vet incoming invitations for collaboration.

STRATEGIC ASSESSMENT FOR PARTNERSHIPS SAMPLE QUESTIONS

Who are our audiences now? Who do we want to reach in the future?

- Will they want to find out about the latest discoveries and technologies?
- Will they enjoy face-to-face interactions with scientists and innovators?
- What topics will they find most relevant and engaging?
- Will they want to explore the potential impacts of new technologies?

What might a partnership bring that would be helpful to our mission?

- Could it help attract new audiences or more diverse audiences?
- Will it bring exciting and relevant new programming and connections with interesting and enthusiastic researchers?
- Will it aid in the development of a new initiative or exhibit area, or bring new resources to complement existing programs?
- Could it help address science, health, or technology issues of special concern to our community?

What capacity do we have for working with university-based partners?

- What staff and resources are available for planning and building partnerships, and for working with researchers on current science and technology topics? What additional resources would we need and what would that cost?
- Do we have a process for evaluating the merits of new partnerships and projects, structuring them appropriately, and managing them effectively? What will it take? Who should be involved?
- Do we have in place the accounting infrastructure necessary to deal with the requirements of federal granting agencies and university sub-awards?

Preparing to Vet Incoming Inquiries

Like that “last-minute phone call,” partnership inquiries can arrive from researchers with little warning and from a variety of directions. Researchers can have a tough time figuring out whom to contact at a science museum about a potential collaboration. It helps to have policies and procedures in place for receiving, analyzing and vetting partnership proposals.

Decide in advance *who* should be consulted within the organization, *what* questions should be asked, and *which* priorities should guide negotiations with the potential partner. Put rapid response contingency plans in place should a late-arriving opportunity prove too compelling to pass up. Some museums have developed standardized forms for collecting and distributing necessary information to stakeholders. These can gather data about the *who, what, when, where, and how* of the proposed partnership, as well as specific information on the funding agency and program, proposal due dates, and start/end dates. They can also gather data on potential resources required, such as staffing, space, equipment, evaluation services, IT support, and necessary sign-offs from key stakeholders. This process will help the organization anticipate the probable costs of the collaboration while also recognizing its benefits.

Generally, the larger and more complex the organization, the more internal stakeholders to consult. These may include managers whose staff will carry out the work and who will need to allocate time, resources, materials. If the collaboration involves a contractual agreement with another organization or a federal funding agency, it will require the involvement of fiduciary and grants management officers.

Some museums set up standing committees and set internal review deadlines for grants and partnership proposals. These provide structure, but they can also hamper the organization’s ability to respond nimbly to compelling joint-venture opportunities. It’s easy to turn down a request for a last-minute letter of support when there’s been little time for discussion and no specific resources or budget. Such an approach presages further problems down the road: the partner may prove unreliable, or lack organization and management skills. However, when the prospective partner is sincere or has a good track record working with the museum, and is now suggesting an opportunity that could be of real value to the museum and its audiences, in alignment with organizational mission and priorities, it may make sense to try negotiating something workable in the foreshortened timeline. This is much easier to do if the potential partner plans to include adequate resources in the budget and possibly a sub-award or subcontract, although it will require accelerated consultation with department staff, accounting, and management. For-

tunately, reasonable adjustments in work plans and budgets can usually be made in the post-award environment by agreement of both parties and with permission from the funding agency.

Preparing to Negotiate

Let's say a request to participate as an education outreach provider in a university-based research center proposal comes into the museum, with several weeks advance notice and with the intention to provide a reasonable amount of funding for the work through a sub-award. The researchers may have a preliminary idea for the outreach – say, an exhibit, or a lecture series. It is now the museum's job to assess the topic area, the suggested approach, and the budget. All of these are negotiable, with the best interests of the intended audiences in mind.

Educational Content

Scientists don't get funding for "an introduction to nanoscale science," or "the biology of cancer" -- they get funding for very specific technical investigations that can sound quite inaccessible to a general audience. Carey Tisdale, an independent evaluation consultant, says that one big impediment to education outreach collaborations occurs when science museum staff become intimidated by their research partner's jargon and the complexity of their work. And yet, that is precisely why the collaboration is necessary. Tisdale says museums need to "own their expertise." The research partners may be experts in, say, condensed matter theory, but science museum educators are the experts in understanding what it's going to take to translate the science in a way that will make it accessible to broader audiences. Like science journalists, the museum interpreters can begin by asking a series of questions: What is the underlying motivation? What challenge is it trying to solve? What's "cool" about it? What hasn't been done before? How might it impact our lives? And, what does *this* term mean, and *that* one...?

Sometimes a scientist will believe they have the perfect way to communicate a particular concept to museum audiences; still, the museum partner should be willing to suggest modifications and alternatives, and the reasons for them. The audience may need a simpler, more introductory approach to the entire subject area and a broader context for the research. It is the museum's job to work with its research partners to find ways to meet audiences where they are, take them gently by the hand, and guide them into these new worlds.

Format

Most people think of *exhibits* when they think of science museums, and yet an exhibit may not be the best way to approach the interpretation of an ongoing research effort. Exhibits are expensive, and they take a lot of time to develop, prototype, test, and install. They're also difficult to update as the research advances. Much interpretation of current science occurs in the form of exhibit hall presentations and demonstrations, through web and new media, or special events. These types of activities are easier to update as the research deepens and new findings are revealed. They also tend to cost less. Be creative here. What synergies can be created with existing programs and partners? Can the university students be involved in developing hands-on demos about their research for family-style interactions? What about science cafés and forums on the societal implications of the research? One of the best approaches is to provide support for a museum educator who can get to know the researchers and their work in depth. That person can then develop innovative programs and activities interpreting the research as it evolves.

Budget

Don't get too far along discussing a vision for the education and outreach program without some grounding in the reality of its cost in relation to the resources being made available. If funding is limited, aim for doing a fabulous job *within* the available resources; or, see if negotiation can produce more resources. It is only too easy to under estimate the cost of developing and carrying out truly effective education outreach programs and exhibits, including staff time and evaluation components. Remember that university faculty may operate in a culture where time is more flexible and graduate students can provide relatively cheap labor. They may underestimate the professional expertise involved in designing effective informal science education programs. They may assume that museum employees are free to take on new projects and subject areas as they come along.

The bottom line in accepting an external offer of collaboration is to obtain a commitment to a budget commensurate with the scope of the plan. That figure should be included in the proposal budget and in your organization's letter of support. If it is not, it should be made clear in the letter that the education outreach program is contingent upon further discussion and negotiation. Without this clarification, the proposal runs the risk of misrepresenting the actual commitment of the Center to its education outreach.

The Museum PI

The person designated as the museum’s PI, or Principal Investigator, is ideally the person who has conducted these planning discussions and negotiations, and will be responsible for carrying out the collaborative education outreach activities and managing the budget. PIs should have the vision, background, experience, and authority necessary to perform these duties and to oversee them on a daily basis. A PI with substantial prior experience, accomplishments, and publications will do much to enhance the Center’s overall proposal. (Resist, however, the tendency to name a high-level executive who will not realistically be involved in leading the effort on a day-to-day basis. The PI needs to be able to commit at least 10% of their time to the effort in order to convince proposal reviewers of significant involvement.) The Museum PI will draft the education outreach narrative that will get integrated into the Center proposal. His or her CV or “biosketch” will be included in the proposal, and often a “current and pending” list of other grant support.

Timeline and Commitments

The museum will need to meet the deadlines of the lead institution in preparing documents such as program descriptions, budgets, letters of support, biosketches, and “current and pending” statements. All internal vetting must take place early enough to submit the final materials to the university for its own internal vetting operation.

Preparing to Administer Federal Grants

Small or new institutions without much prior experience applying for and managing federal grants can lay additional groundwork to help prepare for that time when they are facing a proposal deadline in collaboration with a research institution. In particular, they can designate a grants management staff person, familiarize themselves with the rules and obligations of federal granting agencies, obtain an institutional ID or DUNS number, and work through the process of establishing an Indirect Cost Rate (IDC).

Universities and some large science museums designate grants managers who are responsible for grant reporting and for financial and legal compliance. The organization may have multiple proposals pending at various funding agencies, either as the designated lead organization or as a sub-awardee. In small and medium-sized science museums, a member of the finance or accounting department often shepherds the process. Applicant organizations and prospective PIs may need to register with granting agencies ahead of time. The organization must also complete a preliminary process with one of the federal agencies to establish their “IDC” or overhead rate. It’s best to get this taken care of in advance.

Research & Evaluation and Institutional Review Boards

Research and evaluation (R&E) is an increasingly important aspect of education and outreach (E&O), and grant program officers are looking for evidence that proposed E&O projects plan to incorporate evaluation and use it to improve programs, to provide a measure of accountability, and to inform the larger field through publishing or posting reports. Surveying, observing, testing, interviewing, and other forms of research and evaluation with adults and particularly children (minors 18 and under) are subject to approval by an Institutional Review Board (IRB). The purpose of the IRB is to protect “human subjects” of research, and ensure they are clearly informed about their privacy rights, the purpose of the research, the eventual use of the data being collected, the security of the data, and their right to decline participation. The research sponsor or director must submit the R&E plan to their IRB, including an analysis of potential risks and benefits to participants. Rules surrounding the participation of minors are stricter, and they require parent or guardian sign-off. Funding agencies may require evidence that R&E plans have been certified by an IRB; however, since that process can take some time, it is usually OK to obtain an official IRB commitment to review the R&E plan. The museum should set up a working arrangement with an IRB in advance, and have a clear understanding of its process. Museums can either set up their own IRB or seek an arrangement that allows them to occasionally call upon the services of an IRB based at a local university or other non-profit organization.

Having completed a strategic assessment and laid the groundwork in preparation for education outreach partnerships, science museum leaders may come to the conclusion that it makes sense to proactively pursue partnerships with particular university-based research centers, rather than sitting back and waiting for one to propose. If so, they can prepare a “marketing strategy” to woo potential partners. They may begin by reviewing the attractiveness of the opportunities and services they have to offer.



3. WHAT MUSEUMS HAVE TO OFFER

While the last chapter provided guidance on assessing the benefits partnerships with research centers can bring to science museums and their audiences, this chapter reviews some of the many ways science museums can benefit the research community.

Education and Outreach

Audiences

Science museums reach many more people, and more diverse communities of people, than can university faculty and staff on college campuses. Science museums reach teachers as well as students; adults as well as kids; suburbanites and urbanites; tourists and long-time residents; doctors and their patients, English majors, auto mechanics, civic leaders, the science-attentive, and the just plain curious. The Association of Science - Technology Centers estimates 65 million visits to its 365 U.S. science centers and museums annually. These are the rare places where families can safely and relatively inexpensively spend their leisure time and learn together, particularly when indoor activity is called for. All generations can be engaged, and the conversations that occur between generations catalyzes further learning and exploration. Science museums provide:

- **A conduit to schools and community.** Science museums host school field trips and labs, enriching science and engineering curricula at all grade levels in local districts. Many assist K-12 educators to plan visits that help them address specific U.S. and local curricula frameworks. Many offer professional development and instructional resources for teachers. Some science museums have traveling van programs for schools and community centers. They often provide free family passes for borrowers at public libraries. In some communities, they've introduced multilingual signage, and they often provide thoughtful accommodations for people with disabilities.
- **Reaching beyond the community.** Science museums also reach well beyond their local communities. Some produce popular websites and podcasts, accessible worldwide. Some have YouTube channels or produce local TV programming. Museums also disseminate programs to other museums and educators. The museums in the NISE Network have created an infrastructure for sharing programs and exhibits, accessible at www.nisenet.org/catalog.



- **Credibility.** Visitors have remarkable levels of confidence in the reliability of the information they receive in science museums. Eighty-four per-cent of respondents in a 2008 Reach Advisors – ASTC study described the information presented by science centers as “very trustworthy.”

Venues

While many universities offer public science lectures and programs, their location on-campus can limit the kinds of audiences who will attend. Often, by design, the campus signals an aura of exclusion to the surrounding community; local community members aren’t exactly banned, but neither are they entirely welcomed. Parking can be scarce; campus maps complex. Even publicity for on-campus events tends to stay on campus. It is not surprising that campus science “outreach” events tend to collect familiar audiences – faculty families, students, and alumni.

Science museums, in contrast, are designed as destinations for public audiences – that is their very reason for being. They have already worked out the parking, the scheduling, marketing to the community, access to refreshments, restrooms, coatrooms, and lockers. They know how to meet the diverse needs of families, school groups, tourists, elderly, and other types of visitors. They have infrastructure already in place for volunteers, pick-ups and drop-offs; welcoming areas, reservations; audio-visual, information, and security services. Things in the Museum are designed to be touched, and, if necessary, can endure the enthusiastic release of youthful energy. Science museums are simply better places to engage community audiences than most school or university campuses.

Informal Science Education Expertise

We live in a short-attention span world, and although science is engaging by itself, scientists may not be the best candidates to come up with attention-grabbing ideas. Science museums are highly skilled at capturing the attention of young people. They do it all the time and do it well.”

- Ainissa Ramirez, Yale University

This gets to the heart of the partnership concept between science museums and research centers. It’s a collaboration aimed at inspiring people. Researchers bring the scientific knowledge, the authenticity, and often supportive funding through their grants. Science museum professionals bring educational insight and expertise for shaping engaging and meaningful experiences around the scientific research.

The expertise science museum professionals offer is invaluable. It is sometimes difficult to explain to researchers – many of whom are successful university instructors and mentors - that success in those realms doesn’t necessarily translate to the task of engaging public audiences in informal science education settings. Science museum professionals must design their offerings to attract and to hold audience attention. They can’t fall back on the obligatory rigors of course requirements, tests, and grades. The design of informal science education experiences is both an art and a craft, with an underpinning in theory and prior research. It’s a profession that requires training in science *and* education and often a long apprenticeship in the practical arts of winning hearts and minds through the construction of engaging stories and experiences. While many people, including scientists and engineers, have a real knack for these skills, and others have the potential to develop them with practice and training, most university researchers have not had the time to pursue them.

The reason we’re partnering with a science museum is that they are experienced, and they do very well in communicating with the public and presenting science in a simple way. They’re like our segue to the public, our conduit. Because, we don’t do that very well: we’re not experienced in making sure that our presentations appeal to the public; we’re not good at making exhibits; we’re not good at making events that are public-focused, that appeal to everyone, not just to scientists or students with science backgrounds.

- Ahmed Busnaina, Northeastern University

Inspiring the Next Generation

I am a scientist because I fell in love with science at a young age, when I was exposed to it with my chemistry set and with television shows like 3-2-1 Contact. There weren’t any scientists in my neighborhood, so there was no way for science to find me otherwise. I was lucky. The reason why I do science outreach is to reduce our reliance on luck.

- Ainissa Ramirez, Yale University

Science museums inspire youngsters to learn about the world around them, to be curious and explore, to tinker and to reason. They enrich the student’s experience of the world of research in ways that cannot be so readily accomplished in the classroom. Many scientists report that their initial interest in science resulted from a science museum experience. Museums also help to recruit a more diverse next generation of college-bound science and engineering innovators, widening the proverbial “STEM pipeline.” The fact that

people who enjoy science seek out science museums, and kids go to them expecting to have fun, is a great boon for the success of the educational mission. They enter the museum environment excited and open to learning, expecting to engage and to be engaged.

Beyond Education and Outreach

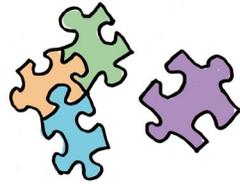
Museums as Sites for Research

Some researchers come to a science museum seeking permission to use it as a site to conduct research with “human subjects.” Working in the museum environment, with its large concentration of visitors, they can collect a more robust set of data in a shorter time period than they could by staying on campus and trying to recruit people to their labs. Kim Kiehl, who has experience both as a tenured Ohio State faculty member and as a science museum vice president, describes the win-win nature of these collaborations:

Our guests see this participation in the science research process as an added value to their experience in the building. For example, we recently had an allergy researcher collect data here on whether children and adults could even identify the various types of nuts that cause common allergic reactions. In the nine days he was set up, he collected data from over 1100 people!

The Boston Museum of Science’s Living Laboratory brings local scientists into the exhibit halls to conduct as well as to discuss their research. Visitors are invited to participate in their research studies and to talk informally with the scientists. For instance, in the Museum’s Discovery Center, some scientists from local universities pursue research on child development and learning, and parents can gain fascinating insights emerging from such studies. These kinds of partnerships help visitors understand more than the results – they also gain insight into the process of research and what is required for validation of a hypothesis. The scientists build funding into their budgets to support museum staff time in setting up the research station and working on interpretation with visitors. For more information: www.mos.org/discoverycenter/livinglab

Of course, all such on-site research arrangements involving human subjects require review and approval by an Institutional Review Board (as noted in Chapter Two), and staff involved in these projects must receive special ethics training in human subjects research.



Museums as Laboratories for Science Communication Skills Development

Science museums can also provide researchers and their students a “living laboratory” for building science communication skills. Some science museums focus specifically on communication and outreach training; others integrate it into a wide spectrum of education and outreach partnership activities.

- With a “Partners in Research” grant, North Carolina’s Museum of Life + Science worked with Duke University’s Institute for Genome Sciences and Policy to help researchers develop skills to participate in conversational encounters with community members and students taking part in their *Genome Diner* activity.
- Funded by a sub-award from an NSF integrative Graduate Education and Research Training (IGERT), the Saint Louis Science Center offered Washington University neuroscience faculty and students summer science communication workshops, coaching in the design and implementation of a themed brain science experience, and practical experience working with visitors at NeuroDay and SciFest events.
- Seattle’s Pacific Science Center, together with Explora in Albuquerque and Pennsylvania’s North Museum, used their “Portal to the Public” NSF award to provide training for researchers in developing and using hands-on demos to facilitate face-to-face encounters with museum visitors.
- At Boston’s Museum of Science, the Strategic Projects Group offers research center partners a menu of science communication workshops, practicums, and internships, as well as a full-year laboratory course for graduate students, and a special workshop program for undergraduates participating in summer research experiences. These workshops focus not just on communication with non-scientists, but also on peer-to-peer communication within an increasingly interdisciplinary research environment.

Museums as Public Forums for Exploring the Broader Implications of Research

Museum professional development programs can also help scientists and innovators build useful skills for participating in broader discussions concerning research. Some science museums have begun to introduce science cafés, forums, and other efforts to increase dialogue and discussion between those developing transformative technologies and those whose lives may be transformed. What ethical, legal, and public policy issues may arise? How should such considerations be taken into account by designers of new technologies and by taxpayers who subsidize their efforts?

The Museum of Science partnership with nanotechnology research centers in Cambridge, Massachusetts paved the way for a citizen forum to address possible regulation of nanomaterials and nanomanufacturing. The City ultimately chartered a course of moderation that earned the respect of industry and of environmental, health and safety advocates alike. Arizona State University's Center for Nanotechnology in Society (CNS) works with the Arizona Science Center to offer graduate students training in methods of engagement with diverse audiences. The students then have the opportunity to work with visitors, receiving mentoring from CNS and museum staff. Says faculty member Jameson Wetmore, "When forced to answer questions about the value of their research, the experience also compels graduate students to think about the broader social and political implications of their work."

Bob Westervelt, director of the Harvard NSF Nanoscale Science and Engineering Center, argues the importance of the quality of self-reflection catalyzed in these encounters:

I think it's very useful for [grad students] to back off from the immediate concerns of solving whatever problem they're trying to solve, and ask, why? Five or ten years from now, what is somebody going to get from this? That's extremely beneficial for the students to think about. Sometimes it actually changes what topics they want to go into.

Making Research Center Proposals More Competitive

Finally, science museum collaborations can make university research proposals more competitive, especially in cases where a "broader impacts," or education outreach component is encouraged or required. The collaboration introduces a credible, professional approach to education and outreach, validated by prior research and evaluation, and backed by impressive data on audience reach.

Communicating What the Museum Has to Offer

After completing an analysis of what the museum has to offer potential university research partners, it may be appropriate to sum it all up a briefing sheet, a web page, or a brochure that may come in handy when reaching out to these potential partners.

A briefing sheet can provide information about the numbers and types of audiences the museum reaches through its various programs, including the number of annual visitors and their demographic diversity. These figures can be broken down into audiences for exhibits, evening lectures, school groups,

van programs, website visitors, and the like. The numbers will be helpful to the research partner as they consider the potential impact of the education outreach plan. Of special interest may be the museum's ability to reach out to traditionally underserved communities. Evidence of the museum's educational impact is always welcome, as are opportunities for broad dissemination.



What awards and recognitions has the museum won? What kind of leadership role does it play in the informal science education community and locally? What examples can be provided of other successful partnerships of this type? Are there testimonials made by previous research center partners as to the value of working with your institution? Does the museum publish or participate in conferences to share knowledge with the broader field?

Develop a menu of options

Having taken the time to assess audience needs and desires, institutional capacity, and future priorities, it may make sense to fashion a menu of options that can be offered to prospective partners. This can also provide some guidance on the amount of budgetary support that might be required. Menu options can always be tailored to the partner's needs and to the resources they can contribute. Going through the exercise of defining and budgeting these options will better prepare both organizations in making choices, especially when a proposal deadline is looming.

The Bell Museum of Natural History at the University of Minnesota has a page on its website entitled "Engaging the Public with Your Science," which markets its education outreach services directly to researchers as a way to help them obtain funding. The web page includes a menu of seven sample education outreach options that can be customized to fit the needs, subject areas, and budgets of potential research partners. These range from science cafés and teacher workshops, to exhibits, videos, and podcasts. The site explains whom to contact at the museum to discuss these options. See www.bellmuseum.umn.edu/ResearchandTeaching/Engaging-the-public/index.htm (accessed November 2012)

Next, recruiting a partner...

4. RECRUITING A PARTNER

Research institutions tend to outnumber science museums in any given community, so it can be easier for a researcher to locate a potential science museum partner than for a science museum manager to figure out what research groups to approach. Where to begin?

Identifying Potential Partners

One place to begin is by speaking with researchers with whom the museum has had a prior working relationship. Let them know that the science museum is looking to expand its coverage of current science and technology and would like to team up with researchers interested in integrating education and outreach into their grant-funded research projects. Ask for advice on whom to approach and how. Museum board members can also provide advice. They are usually very well connected.

If you have targeted a specific topic area, find out if a local research university has a center, department, or individual investigators active in that area. Explore their websites. Troll the listings of grant awards that science research funding agencies like the National Science Foundation publish on the web. For nanoscale science and engineering programs, check www.nano.gov, the National Nanotechnology Initiative's website, and click on Nanotechnology Centers. The centers are organized by federal science agency. Check if any are nearby. It sounds obvious, but do a Google search with the name of your local college or university and "nanotechnology" or "nanoscience" or whatever topic you are pursuing. Your best bets are likely to be NSF-funded centers, because NSF's Broader Impacts Criterion incentivizes researchers to include plans for education and outreach in their proposals.

Some science professional societies, like the Materials Research Society, have education outreach committees and can provide guidance about members active in your area. Some professional societies maintain national speaker lists or databases of researchers willing to consult, volunteer, or provide networking advice.

If you don't have a specific topic area to target, and are interested in local connections with a variety of active researchers in your area, begin with large research universities. If none are reasonably close, look at colleges with strong science and engineering departments. Get to know the research specialties of these institutions. Visit their websites; attend campus talks; identify their best science communicators. Browse campus bulletin boards to find



local symposia and events not listed on public calendars. Read the university gazette or e-letters from the science and engineering schools. Who's publishing? Who's work is being reported in national and international journals? These folks may be more likely to be involved in high profile, grant-supported research activities. Google faculty members and find those who already participate in public outreach or write articles for lay audiences.

Most universities and research organizations will have "Sponsored Research" administrators and press officers who recognize the value of getting researchers and their work known in the wider community. You may try calling to let them know your museum is interested in outreach collaborations with scientists. Seek recommendations for scientists whose work may be of particular interest to more general audiences. Ask to be put on the email list for research news and press releases. Press officers tend to know which researchers enjoy outreach and are good at it, while sponsored research administrators are in a position to advise researchers on their broader impacts requirements and the opportunity of working with your museum.



Reaching Out

All your advance preparation comes to bear when you begin to reach out to prospective research partners. It can be a very rewarding experience, whether or not it results in a specific collaboration in the short-term.

Unless they are faculty super-stars and super busy, you may be able to make direct contact with researchers you've identified. Make sure you have read up on their research or gone to one of their talks. Most scientists regard science museums fondly, and take their families when they can. They have an intrinsic interest in science museums, which after all, celebrate scientists the way art museums celebrate artists.

It's not too difficult to pick up the phone and call a researcher or department head and ask if you might schedule a meeting to explore whether there might be ways to build stronger ties between the museum and researchers in their group or department. Let them know you've heard about their work and are interested in finding out more. Offer to brief them on what's new at the museum, and how they and their students might want to get involved there. Mention that you'd be interested in working with them on any upcoming funding proposals that may involve an education outreach or public engagement component.

You might give them complimentary passes to the museum, and invite them

to call when they plan to visit. Perhaps the museum director could host a reception for researchers in your area, including board members and senior staff. Invite department heads and senior faculty. Let them know you are eager for their ideas on ways to collaborate to advance science literacy in the community. Ask them to suggest exciting and important new research areas to share with your audiences. Here's some additional advice from Kim Kiehl:

Don't be intimidated. Sincere interest is always welcome. It's okay if you don't know the lingo or aren't up on the latest. You'll never know what may come of it if you don't try. We did an open house meeting for faculty [at Ohio State University], issuing them an invitation from a high-level university executive to come spend time [at our museum] and tell us what we could do better and imagine how we could work together. We gave their families passes for the day while we held the meeting, and over 200 faculty came on an August weekday. Many of our partnerships have grown directly or indirectly from this event. It was also at this event that we gave guidelines for working together, which includes the timelines for grants, etc.

Remember that these efforts are about developing relationships and building bridges between people and organizations. It may take awhile before the bridges bear much traffic. Stay in contact, and check back every so often.

Keeping Abreast

One other strategy can assist with the timing of your efforts: Keep abreast of new program announcements and funding opportunities from federal and state science funding agencies. For example, at www.nsf.gov, you can find a list of all upcoming program solicitations. You can subscribe to daily or weekly email alerts. Don't confine yourself to lists specifically targeting science education; it will be useful to learn about large multi-investigator research efforts that could benefit from education outreach collaborations. NIH, NOAA, and NASA also occasionally announce funding opportunities that contain strong education and outreach components. Once you've become familiar with your local university research scene, you may be able to anticipate which researchers are likely to be interested in responding to these new opportunities. If so, suggest a collaboration for education and outreach.

The writing of new grant proposals is a never-ending feature of a university researcher's career, and one successful education outreach collaboration can lead to others with the same set of investigators, or with other investigators who have been tangentially involved. The partners can establish a track record of success that helps them to continue finding support for expanding and deepening the quality of their work.

Small Steps, Big Impact

One good way of testing the waters for a potential partnership is to invite local research centers to participate in a short-term project that will serve to break the ice.

A good model for this approach is NanoDays, the annual event begun by the Nanoscale Informal Science Education Network in 2008. [www.nisenet.org/nanodays]. NanoDays is a designated week, typically in late March/early April, targeted as a time for informal science education organizations and nano research centers to collaborate together on special outreach events. The NISE Net provides a free NanoDays kit to the first couple of hundred takers, and a downloadable digital version. The kit is designed as a self-contained core set of materials around which other local activities can crystallize. It includes proven hands-on demonstrations and activities, media, graphics, guides, and other supporting materials.

This has been awesome actually. We got this great kit; we had all these ideas. We had about 50 volunteers – undergrads, grad students, faculty – all reeled in to help. We put together a whole package of open house and school visits and museum visits. Just doing it we learned a lot. Our open house had 250 people on a Sunday afternoon, and we had a wonderful time, building nano-tube balloons and great demos and multimedia. We went into an elementary school the next morning with 63 5th graders, and we had nine stations with groups of kids rotating every five minutes, and it worked swimmingly. Five minutes just captured their attention span; we were perfectly matched and it went off without a hitch.

*- Jerry Floro, University of Virginia
(Partnered with the Science Museum of Virginia)*

The NanoDays concept and the NanoDays kits have proved extraordinarily successful at catalyzing new relationships between science museums and research centers. Google “NanoDays” and you’ll find webpages all over the country describing local events.

These NanoDays collaborations can be the seeds that sprout into more robust collaborations.

We have already partnered with one of the nano research centers on three grant proposals that we hope will provide funds for training museum staff in their labs, support for guest researchers volunteering here, and, of course, future NanoDays collaborations.

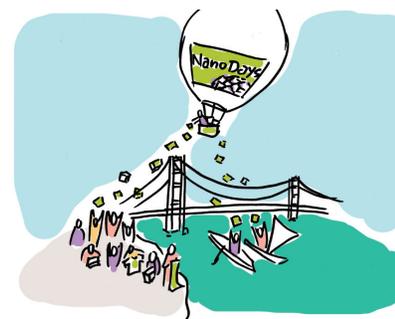
- Christine Roman, Saint Louis Science Center

It’s relatively easy to think of other short-term activities that could function similarly to NanoDays as catalysts to further collaborations, and the calendar is full of special science and engineering awareness weeks. In 2006, with funding from their NSF “Portal to the Public” grant, Seattle’s Pacific Science Center sponsored a four-day Polar Science Weekend in partnership with the Polar Science Center at the University of Washington, featuring several dozen researchers with activity stations and demonstrations. This became an annual event, coupled with education outreach workshops for the participating scientists. NASA then provided funding to build a permanent museum display on polar science. Meanwhile, the campus collaboration continued to gain momentum. According to senior vice president Dennis Schatz,

This coming weekend [April 10-11, 2010] is our first “Paws on Science,” a research weekend that involves researchers from the entire campus. (The name comes from the UW mascot – the husky dog.) What is most exciting regarding this event is that it is funded directly by the UW marketing department and alumni association, rather than depending on grant funding. UW has also embraced the idea of including professional development in these programs and has funded workshops for participating scientists

What started as a good idea for a fun weekend at the science museum, in collaboration with a single research group, has now expanded into a very robust university-wide partnership, with much to offer the larger community.

Small steps often DO lead to big IMPACT.



5. PARTNERING ON A GRANT PROPOSAL

Let's say you have recruited a university-based research partner who has been impressed by your pitch for developing a terrific education outreach program connected to their research, and they want to work with you. You need some funding, and your choice is to go in either as a partner/sub-awardee on their next research proposal, or to develop a new proposal to a program that directly funds education and outreach. In this chapter, we will discuss in further detail these potential sources of funding, and how to approach them.

Direct Award or Sub-Award?

Grant funding for collaborative education outreach activities can come as either a direct award to the science museum or as a grant sub-award from the university-based partner. This guide emphasizes the opportunities available from sub-award funding for several reasons: (1) They are under-utilized in the science museum field; (2) They are particularly well-suited to supporting science museum – research center outreach partnerships; (3) They allow the partners to remain focused on the local community; and, (4) The pool of direct funding for informal science education is shrinking, while the number of qualified applicants is increasing. Nevertheless, since direct funding is more familiar to most, let's begin with a quick overview.

Direct Funding

All of the usual sources of grant funding for science museums and other informal science organizations welcome proposals that show strong collaboration with a university-based science and engineering research partner. Here are some of the major federal sources of funding for informal science education:

National Science Foundation: Division of Research in Learning in Formal and Informal Settings (DRL) "Advancing Informal STEM Learning" (AISL)

This is the most robust of the informal science education funding programs, investing in "research and development of innovative and field-advancing out-of-school STEM learning and emerging STEM learning environments." Although descended from the former "Informal Science Education" program, which in past years funded many individual science museum exhibits, programs, films, and outreach partnerships, this latest iteration focuses on exploring, analyzing, and *advancing knowledge* of effective approaches to



out-of-school learning. Proposals must include a well-integrated and rigorous evaluation component. These investments are intended to advance the field as a whole; not simply serve local needs:

The program invests in projects that promote lifelong learning of STEM in a wide variety of informal settings. Funding is provided for projects that advance understanding of informal STEM learning, that develop and implement innovative strategies and resources for informal STEM education, and that build the national professional capacity for research, development, and practice in the field.

The annual funding cycle for this award is fiercely competitive, even more so now that the program has expanded to include university-based informal science education research. Applicant organizations can include television, radio, and web media producers, community and after-school programs, citizen science projects, science festivals, zoos, and aquaria. Among the nation's science museums, those with the infrastructure, budget, and expertise to write competitive grant proposals have a distinct edge. Depending on federal appropriation levels, only about 25-35 proposals get funded each year. About 650 pre-proposals were submitted to the NSF ISE program during 2010; roughly half of these were invited for full proposals.

www.nsf.gov/pubs/2012/nsf12560/nsf12560.htm

The National Institutes of Health: Science Education Partnership Award

The National Institutes of Health (NIH) hosts one program that offers support for informal science education research and learning alongside K-12 and university education and research. This is the Science Education Partnership Award (SEPA). The SEPA program was recently moved to the Office of the Director, in the Division of Program Coordination, Planning, and Strategic Initiatives.

SEPA is designed to improve life science literacy throughout the nation through innovative educational programs. SEPA-supported projects create partnerships among biomedical and clinical researchers and K-12 teachers and schools, museums and science centers, media experts, and other educational organizations.

As the name implies, this program encourages partnerships between educators and health science researchers. Science museums are welcome to apply directly for support. The five-year awards include funding for development and dissemination of health science programs, exhibits, and media. They require rigorous evaluation components.

Total funding for SEPA awards varies from year to year and has even skipped a year. Only about ten new awards are issued annually, so competition is tight. SEPA funding has supported the development of numerous science museum exhibits and programs, all based on collaborations with university-based research partners.

www.dpcpsi.nih.gov/orip/od/science_education_partnership_awards_index.aspx

Other Federal Funding Agencies

The National Aeronautic and Space Agency (NASA) and the National Oceanographic and Atmospheric Agency (NOAA) also offer programs from time to time in support of informal science education efforts, as does the Institute of Museum and Library Sciences (IMLS).

NASA has a variety of active programs encouraging what it calls EP/O, or Education and Public Outreach, and has had a long-standing interest in collaborations between research centers, schools and science museums. NASA also sometimes funds and distributes science museum programs and exhibits and has supported the development of networks addressing particular topics, such as solar research, the Space Shuttle program, the International Space Station, and Mars exploration. Find the NASA Informal Science web portal at www.nasa.gov/audience/foreducators/informal/index.html

NOAA has become more active in formal and informal science education programs in recent years and has funded collaborations between research institutions and museums and aquaria. Check out NOAA's Office of Education webpages at www.oesd.noaa.gov/index.html and grant program listings at www.oesd.noaa.gov/grantprog.html

The IMLS has awarded funding to informal science education institutions to partner with research centers and libraries, to improve collections and accessibility, and to build libraries of digital learning resources. Check out the IMLS webpages at www.imls.gov

Sub-Awards from University Research Grants



The number of awards and amount of funding awarded to university-based research centers from federal agencies dwarfs what is directly available to science museums and other informal science education developers and providers. When museums partner with local university researchers in national research funding competitions, they reap the advantage of their unique regional identity. Instead of competing against all the other informal science education organizations in the country, they are sometimes the single best

choice in their region to serve as an education and outreach partner for a university-based research group.

Research center grant opportunities are preferable to individual investigator opportunities because center awards tend to be quite large and can last five years or more, plus they are often renewable. Research center budgets are larger and more discretionary than individual investigator budgets, so they can provide better resources to support a more comprehensive and higher impact approach to the education and outreach components. They can also support evaluation efforts meant to advance field-wide knowledge through publication and conference presentations. The scale of the effort merits a true sub-award to the science museum, and that makes the museum eligible to receive indirect cost recovery, or IDC. The IDC reimburses the institution for some of the infrastructural costs of doing business – the kinds of hidden costs that can plague organizations managing small individual partnerships. Meanwhile, the effort and resources required to produce a sub-award component of a research center proposal are much less than for a full direct award proposal. And of course, a good education and outreach collaboration can help the research partners win high marks from reviewers.

Sub-award funding from research centers is truly one of the great areas of untapped potential for enhancing informal science learning. There are more than a dozen federal science and engineering research funding agencies. Many of them welcome proposals that include education and outreach components. But only one of them routinely *requires* grantees to seek to share their research more broadly with public audiences, the National Science Foundation.

National Science Foundation

Research proposals going into the National Science Foundation's many science and engineering directorates offer the best opportunities for science museum sub-awards, because of the NSF's explicit commitment to enhancing "the broader impacts" of research.

The Broader Impacts Criterion Encourages Museum Partnerships



The "Broader Impacts Criterion," (BIC), and the "Intellectual Merit Criterion" are the two major frameworks through which NSF peer-review panels are instructed to assess research proposals. The BIC asks reviewers to consider:

How well does the activity advance discovery and understanding while promoting teaching, training, and learning? How well does the proposed activity broaden the participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc.)? To what extent will it enhance the infrastructure for research and education, such as facilities, instrumentation, networks, and partnerships? Will the results be disseminated broadly to enhance scientific and technological understanding? What may be the benefits of the proposed activity to society?

-Chapter Three of the 2011 Grant Proposal Guide

www.nsf.gov/pubs/policydocs/pappguide/nsf11001/gpg_3.jsp#fn41

NSF also provides a 2007 document that describes representative activities that address the BIC, and, these include, under the topic heading, "Broad Dissemination to Enhance Scientific and Technological Understanding," the following examples:

- Partner with museums, nature centers, science centers, and similar institutions to develop exhibits in science, math, and engineering.
- Involve the public or industry, where possible, in research and education activities.
- Give science and engineering presentations to the broader community (e.g., at museums and libraries, on radio shows, and in other such venues).
- Make data available in a timely manner by means of databases, digital libraries, or other venues such as CD-ROMs.
- Publish in diverse media (e.g., non-technical literature, and websites, CD-ROMs, press kits) to reach broad audiences.
- Present research and education results in formats useful to policy-makers, members of Congress, industry, and broad audiences.
- Participate in multi- and interdisciplinary conferences, workshops, and research activities.
- Integrate research with education activities in order to communicate in a broader context.

(www.nsf.gov/pubs/gpg/broaderimpacts.pdf)

Science museum partnerships are practically written right into NSF research grant proposal guidelines!

Helpful Facts about NSF

Congress currently funds NSF at between six and seven billion dollars a year. Each NSF “Directorate” administers funds for research, and the Directorates span almost all areas of science, engineering, and technology - even social, behavioral, and economic sciences - as well as numerous cross-cutting programs. Each of the Directorates contains divisions and each of these divisions offers grant funding in specialized areas of research. All of these funding programs require researchers to address the Broader Impacts Criterion as well as the Intellectual Merit Criterion, and therefore every applicant has the opportunity to strengthen their proposal with an education outreach or public engagement effort conducted in collaboration with a science museum. At www.nsf.gov one can scan the lists of current and upcoming grant opportunities in all divisions, and sign up for alerts on new postings. One can also find lists of all current awards and dig into locally-based NSF-funded research. The NSF website does not include “center funding” as a category; however it can be used as a search term. Many of the center funding opportunities come up under the category “crosscutting.” All nano-related research centers and networks funded by NSF and other science agencies are listed at www.nano.gov/centers-networks

Directorate of Education and Human Resources (EHR) and NSF-Wide Initiatives

EHR is the NSF Directorate that houses the Division of Research and Learning in Formal and Informal Settings (DRL), which administers the Advancing Informal Science Learning program discussed earlier. This Directorate, however, also funds other programs focused on STEM education, STEM education research, and on undergraduate, graduate, and early-career training of scientists and engineers. Science museum partnerships with university investigators can be applicable in some of these areas. For instance, the Museum of Science partnered with Northeastern University and the Boston Public Schools on an NSF DRL ITEST (Innovative Technology Experiences for Students and Teachers) program to aid high school teachers in introducing engineering design activities into their classrooms.

The 2010 program solicitation for the Integrative Graduate Education Research and Traineeship program (IGERT), an NSF-wide endeavor, indicates that “all IGERT projects must now specify how students will receive training in communication of the substance and importance of research to non-scientist audiences.” [NSF 10-523]. Preceding this, in 2005 the Saint Louis Science Center began an IGERT-funded graduate student training program partnership with Washington University.

NSF has also been generating opportunities for cross-cutting collaborative proposals for networks, centers, and programs that bridge the worlds of research and informal science education. The Nanoscale Informal Science Education Network (NISE Net) is one such example of a large award going to a collaborative effort among science museums and research organizations, with funding from several NSF science and engineering research directorates. In 2010, NSF launched a large Climate Change Education Partnership (CCEP) Program, designed to encourage a network of partnerships between climate change researchers, educators, and informal science learning organizations. The Science, Engineering and Education for Sustainability (SEES) was launched in 2011. Science museums that have already begun to develop relationships with research centers will no doubt be better prepared to demonstrate competence and provide leadership in these cross-cutting areas.

Partnering on a Grant Proposal

Start early. If you start early, you will have time to generate and discuss valuable ideas and options, and to vet the proposal with stakeholders at both organizations. You will need to work on balancing the proposed budget with the proposed activities until they are in true alignment. There may need to be an evaluation plan and a commitment from an outside evaluator, who will of course have to see what is in the proposal in order to do their part. You may be required to supply letters of commitment and examples of prior work, as well as curricula vitae and “current and pending” statements, formatted in a particular style.

Advance Preparation

In **Chapter Two: Laying the Groundwork at Science Museums**, we went over the internal assessment processes that can help prepare your organization to develop a education outreach plan with university-based research partners that will support institutional goals and serve museum audiences. We discussed the preparatory steps your museum can take to be ready to submit a direct proposal or to participate as a sub-awardee on a university’s research proposal. These included registering with federal agencies, authorizing institutional grants administrators, establishing an indirect cost basis (IDC), arranging access to an Institutional Review Board, and selecting a museum PI.

Research and Evaluation

Informal science education funding agencies are increasingly examining ISE projects for evidence that they are designed, structured, and evaluated in a way that will produce field-enhancing knowledge about the validity and

impact of various approaches. The more you conceive of your effort as a research project, the better it will fit with most funding agency criteria, and the more helpful it may be to others down the road. Do you have a logic model? What are your goals? How will you assess whether you have reached them? On what basis have you chosen your approach? Is it innovative? What is the potential to the field? Is it adaptable to other environments? Is it scalable? Does your team have the appropriate credentials and expertise? What plans do you have to share what you learn with other professionals? Do you plan to post or publish your findings? Strong proposals refer to prior research to help justify their approach, and they outline evaluation plans appropriate for informal science education settings.

Keep in mind that while robust plans for research and evaluation are often centerpieces of an informal science education proposal to a program such as NSF's AISL, they are not always considered essential by your research center partners, nor by their program officers. STEM researchers are more conditioned to think of the *science* as the research, and of education and diversity efforts as accompanying *practices*. These attitudes are changing, and they shouldn't necessarily deter you from trying to enroll your research center partners in supporting more rigorous evaluation efforts. Such efforts may end up reflecting well on the Center's work, especially if they are published. However, rigorous evaluation plans can be expensive to carry out, dampening your partner's enthusiasm for them. And, especially in a sub-award to a large research grant, the amount of proposal narrative space allotted to describing such plans is sharply curtailed. Nevertheless, it's simply good practice to include plans for at least formative evaluation, and to include time in the schedule for making adjustments to programs and exhibits based on that evaluation.

The Proposal Narrative

In many ways, the most difficult part of writing a proposal is keeping the many required aspects of the research plan to a critical page limit. With an education outreach sub-award from a university research center, the lead institution may not be able to devote more than a few paragraphs to the proposed plan. Thus, this narrative section needs to be very clear, consistent, and succinct, describing goals, key elements, and measurable impacts, as well as referencing prior work, and providing evidence of the competence of the organization and the team. The education outreach plan should be specific about target audiences, numbers and demographics. The reviewers will want to know that the budget provides specific funding in support of these activities.

Budgeting a Partnership

Everything costs something, and this is true even if the partners are volunteering time and resources. For example, an agreement to host a series of lectures or public presentations or a special event requires staff time planning, publicizing, managing, and cleaning up from the event. Such an event will also consume other resources, like refreshments, parking spaces, heat and electricity, water, and space that could have been used for a paying client, since many museums rent out their venues for private events. An agreement to invite graduate students to serve as volunteers or interns will necessitate recruitment, training, and supervisory staff time. An agreement to accept an exhibit designed by a researcher and his or her graduate students may result in many hours of exhibit planning and production time to ensure its suitability for museum audiences.

Try to take all these "hidden costs" into account before signing on to a partnership agreement. Museums are particularly vulnerable on this front because they are non-profit, mission-oriented institutions, and their staff are motivated to serve the community more than the bottom line. Open up a spreadsheet and start doing the numbers. You'll want to ensure that you do not over-promise what you can deliver at a given funding level. Explore production schedules and allow for contingencies. Understand how small differences in schedule and personnel can effect the bottom line. A spreadsheet can also help you map out the proposed activities month-by-month and form realistic expectations. Draft a budget early on, based on initial planning, and revise and adjust as the plans develop.

Indirect Cost Recovery

The first budget item to take into account is "indirect cost recovery" or IDC. Some funders do not provide IDC. Some cap it at a certain percentage. Others negotiate a rate, institution-by-institution, based on complex formulas. Typically, an institution will go through the IDC determination process with the federal agency from which it most frequently seeks funding. For many science museums, that agency is NSF. Other federal agencies usually accept a rate established by a sister agency. However, many private donors and foundations do not allow IDC recovery at all, or instead require specific line-item delineation. The NIH SEPA program allows just eight percent, even though NIH allows very high rates for university research centers. Both NIH and NSF IDC rates can range well over 50% in university environments. Obviously, the higher the IDC recovery rate, the better for the institution as a whole. The grant or sub-award is not only supporting terrific work, fully-funded, but is also paying its fair share of the institution's basic infrastructural "overhead" costs for doing this kind of business. Of course, the downside for the PI and key

personnel is that less of the funding will go toward direct program costs. For example, if the grant provides a \$100,000 sub-award and the institutional IDC rate is 30%, then \$23,077 of the \$100,000 will be allocated to the organization's general operating funds, leaving \$76,923 for staff time, benefits, and other direct expenses.

Staff Time

The next most important item on your spreadsheet is the staff time the project will require. This is an estimate of the percentage of time or number of hours for each individual working on the project month-by-month over the course of the project. Include estimates of time for meetings, staff supervision, prototyping, formative evaluation, and documentation. Hourly staff costs are then augmented by your institution's benefits rate. If that subtotal comes out higher than the budget can allow, stop there and reduce the project's aspirations. It's tempting to try to fudge it, but you risk disappointing yourself and your partner, either unable to fulfill contractual obligations, or contributing staff time and other resources from general operating funds. You can't hold a bake sale to finish an exhibit. Neither can you go back to the funder and say, 'oops we goofed; we actually need twice as much as we budgeted.' Try to build a track record of completing successful projects on budget and on time. By the way, if the project requires you to hire new staff, try to anticipate the amount of time it may take to recruit and hire them.

Research & Evaluation

The research and evaluation components could require some combination of internal and external labor and expertise: designing a plan, developing survey and assessment instruments, administering them, analyzing results, and reporting. If you include front-end and formative evaluation, consider the costs of making revisions to your programs based on the interim results. Your evaluation plan will fail to inspire confidence if no budget has been allocated for it.

Other

Be sure to budget for necessary equipment, materials and essential outside services. Try to think through everything you will need at each stage of the process. If special events are involved, there will be courtesy costs for parking, refreshments, as well as printing and signage. If running workshops, there will be "participant support" costs. If working with graduate students, YOU WILL NEED TO FEED THEM. Consider photographic documentation of your events, and recordable electronic media. Will you be presenting at a conference, or participating in a reverse site visit? Build in funds for travel. Check the program guidelines carefully. Some programs may require you to travel to a yearly PI meeting.



Using Your Spreadsheet

Your budget worksheet is an internal document that does not have to be shared with your partner. It is for you and your organization to use in understanding what the proposed activities will cost, and to make adjustments as the budget allows. If you realize you need more funds than the current amount under discussion, you will need to try to negotiate either more funds or a cut back on the scope of the plan. Sometimes the best decision is to start in a smaller and more limited fashion than both partners had originally brainstormed. If that more limited scope of activities proves very successful, perhaps there will be a way to find funds to expand the program down the line.

Grants Officialdom

Once the partners have come to an understanding about the scope of work and the amount to budget for it - and these plans have been vetted by both organizations - finance or grant administrators at each organization can prepare official budget forms, subcontract documents and scopes of work to be signed by the cognizant officials.

The budget form used by NSF, Form 1030, has more generalized expense categories than your budget worksheet; however, the budget justification form offers the opportunity to clarify the basis for particular lines on the 1030 that aggregate your worksheet budget assumptions. The required forms need to be orchestrated and submitted into FastLane, NSF's online proposal portal. Other agencies have other portals; for instance, NIH has the "eRA Commons." Detailed instructions are provided on the program solicitation and the website, and contact information is provided for program officers who can provide further counsel. Don't wait for the last minute to file, since the increased traffic can induce problems, and filing deadlines are strict.

Partners may also need to provide institutional letters of support, bio-sketches for key personnel, current and pending statements, and other institutional documentation. Then, after all the submitting is done, it may take six months or more to find out if funds will be provided.

Notification

Alas, there have been more than a few cases in which a university-based PI has agreed on an outreach plan with a partnering science museum, and has written it into a center proposal, even including a letter of support from the museum, and then failed to contact the science museum once they have received word on the outcome of the proposal. This is mildly annoying in the

case that the proposal was unsuccessful, but of considerable concern when a proposal has been funded, and the education outreach plan has seemingly been forgotten.

This is where it is helpful to have, if not an actual sub-award built into the proposal ahead of time, then, at the very least, a letter of agreement (LOA) or memorandum of understanding (MOU) from the lead organization before providing a letter of support. That letter of support should include mention of the agreed-upon budget. Try also to obtain a copy of the proposal narrative. Then, look up the program solicitation number and award notification date, and then put a note in your calendar.

Getting Started

Once the award comes in, it's a good idea for the lead institution to call a meeting of all the partners and collaborators, if only to shake hands, pat each other on the back, and remind each other of what you agreed to do and the timeline for doing it.

Although everyone will be in the midst of other projects, the best collaborations hit the ground running. There are contracts to be signed, papers to be filed, contact lists to be assembled, and a governance structure to be put in place. Sometimes changes to the plan will have resulted through negotiations with the funder. Sometimes, conditions on the ground have changed, or key personnel have moved off, so some adjustments may be required. Once the grant has been awarded, the clock starts running. If you planned to accomplish a certain set of deliverables in the first year of the grant and to spend a certain amount of money, you need to get going. You may have to hire new staff and train them. While it is true that you can sometimes get "no-cost" extensions on grants and roll over funds from year to year, that route is best regarded as a fallback.

Time to get started!



6. PARTNERSHIP STEWARDSHIP

Institutional collaborations are challenging. Each organization brings to the table its own mission, priorities, organizational structure, financial model, and operational calendar. Staff turnover at any level can be a major factor. Accountability issues between organizations can be difficult to adjudicate.

Not surprisingly, the health of institutional collaborations often rests on the strength and quality of the personal working relationships between individuals at each organization. Key factors: mutual respect, trust, alignment on common goals, frequent communication, and follow-through on shared commitments to one another and to funders.

Each partner brings essential resources and expertise to the collaboration. Alignment with core institutional goals helps ensure that individuals on the front lines of the collaboration have the necessary buy-in and back-up from their chain of command. Together, the partnering organizations can achieve key goals that they could not accomplish on their own.

Principles of Good Stewardship

Incorporate good stewardship principles from the very first planning and proposal development efforts and set up structures that support good stewardship throughout the life of the collaboration. Some basic principles:

The partners are clear about their common goals and assigned roles and responsibilities. These expectations should be clearly defined and put in writing, which will help keep a record and facilitate institutional memory in times of transition. Formal grant-funded collaborations need these signed, sealed and delivered before funding begins. Less formal partnerships can benefit from drafting a Letter of Agreement (LOA) or a Memorandum of Understanding (MOU) between the parties, even if no contract or financial commitment is on the table. These help to ensure explicit "buy-in" at the highest level of each of the partnering organizations.

The partners have designated liaisons. One of the biggest frustrations for partnering organizations occurs when there is confusion over who has authority to make decisions on each side and who serves as the point person on collaborative efforts. This issue came up frequently in surveys of researchers who had worked with science museums (RK&A, 2006). The designated liaisons should be named in the written documents, and their replacements should be appointed quickly if there is turnover. Try to roughly match levels of responsibility, authority, and experience. It's not a good idea to charge a new employee fresh out of college to be the liaison to a university PI.

The designated institutional liaisons keep in touch regularly. They don't hesitate to pick up the phone or send emails if there are questions or concerns. Periodic face-to-face meetings with key players are very important in maintaining healthy partnership relationships. Emails, phone conversations, collaborative wiki sites, and regular reporting can help maintain relationships and assist in their operations, but nothing beats face-to-face meetings in nurturing the kinds of bonds that lead to a true sense of collaboration. Designated liaisons should also be copied on all direct communications between financial and grants management teams.

The partners do what they say they are going to do. This is a no-brainer, but accountability is an essential aspect of the arrangement. If circumstances force a change in plans, partners should be notified and consulted on alternatives. Partners also need to coordinate their compliance with funding agency and institutional requirements. Significant variations in spending or timeline from what was initially proposed may require specific approval by the university and the funding agency program officer. Elements required for annual reports to funders need to go into specific formats and to arrive in a timely manner. Typically they go through a number of steps before publication and submittal. Partners need to give each other plenty of advance notice. Grant related reporting and site visits and reverse site visits should be posted in everyone's calendar.

The partners help each other look good. The sub-awardee organization should be prepared to help their partner demonstrate to the funder the positive impact of their efforts, including the numbers of people reached, demographic data, evaluation results, publications, and so forth. Photos documenting the education outreach programs and faculty involvement are especially useful, as are websites and news coverage. Funding agencies want to know that the efforts are sound and the impact is real. Likewise, science museums benefit from the exposure of their good works to funders and to their board members and donors.

Partners share names, credits and logos. They understand how both organizations and key players prefer to be credited in documents, press releases, websites, marketing materials, and publications. They share high-resolution copies of their partner's logos. They need to follow specific funding agency requirements, including grant numbers, credits, content disclaimers, and specific acknowledgement wording. Press releases, signage, marketing materials, and scholarly articles that involve both organizations should be offered for reviewed by partners ahead of publication.

Calendar awareness is critical. University and science museum calendars are typically quite different. Science museums tend to be busiest on weekends, holidays, and in the summer, precisely the times when universities tend to lose faculty and students to vacation and travel. Academic schedules are decisive factors in planning collaborative efforts.



Do not expect to be able to advance a joint project or proposal during the month of August, when many university researchers take vacation breaks. Other summer months may be slow as well. Different schools at a single university may have varying semester schedules and holiday breaks; these can determine whether researchers and their graduate students are available when you would most like their help – for instance, if you want to host face-to-face guest researcher encounters when your museum is full of families on holiday. (Provide museum passes for their families too!)

Time management and other forms of courtesy. Time management is a critical area for faculty researchers as well as for science museum staff. Research faculty tend to have complicated and irregular schedules teaching courses, advising, conducting laboratory research, meeting faculty commitments, attending scientific meetings, writing and reviewing grants, and so on. In general, researchers want to contribute their expertise; they do not want to get involved in organizational, operational, or administrative details. In all cases, try to be clear from the start what roles the research partners would prefer or not prefer. When researchers have committed to work with your science museum on a public engagement project, respect their time, and make it as easy for them as you can. Work with their administrative assistants or their education outreach directors. Provide directions, parking, badges, escorts. Graduate students can be more flexible with their time, but they will deeply appreciate refreshments, vouchers for the cafeteria, and places to safely stash their backpacks. The RK&A study found that if partnerships involve extensive volunteer programs for scientists, these succeed best when the science museum commits “requisite staff time, money, and resources.”

A little appreciation goes a long way. The researchers with whom you collaborate are probably going out of their way to make their commitment to education outreach a serious one. It can be a little stressful if it means venturing into areas beyond their comfort zones. Give back to the researchers you work with. Recognize their efforts. Write thank you notes. Share photos and videos of your joint events. Celebrate both minor and major accomplishments along the way.

The partners cultivate cross-cultural insight and understanding. While, the individuals that inhabit these distinct types of organiza-

tions may come from different backgrounds, they share a love and appreciation of science. It's helpful if the science museum participants have a background in research; if not, they should do their best to get to know and understand the university research center culture. They should also try to share with their academic allies the constructivist learning culture of science museum and informal science education communities. NISE Net offers for university researchers the guide *Bringing Nano to the Public: A Collaboration Opportunity for Researchers and Museums*, by Wendy Crone. It provides a primer on science museums and on the practice of informal science education. www.nisenet.org/catalog/tools-guides/bringing-nano-public



The partners open doors to each other. Sometimes the simple courtesy of providing hassle-free access can help build friendship and familiarity. The research center PI can be recognized by the Museum director and invited to special events. Museum memberships and passes, can be offered to partners and frequent guest researchers. In turn, the university folks can provide campus website and wireless accounts for the museum staff who visit frequently. A consultant-level university ID card can help the museum educator gain access to campus libraries and scientific journals to help them do background research. A parking pass provided for on-campus meetings is often a necessity. If the research center has an email list and online calendar, museum staff can be put on it and kept informed of seminars, symposia, and other activities. The more deeply the museum staff understand the research, the better they will be at translating it for broader audiences.

Collaboration on educational content. The science museum partner owes the research partner a high level of professionalism in ensuring the accuracy of the content it develops and presents. Museums should be able to guarantee that the staff they hire or assign to the project have the proper training and the necessary skills to do a good job. These of course include science education and communication skills, but if the job involves interpreting current research for broad audiences, then the staff person should either arrive with or quickly acquire a good understanding of the field of research. Ideally they have some research background of their own. Training in journalism or science journalism is often helpful. On the other hand, the researcher partners should allow the science museum team a level of editorial independence over content that ensures they are not merely acting as public relations liaisons for the university. A science museum's integrity and the public perception of that integrity is one of its most valuable assets. Eighty-four percent

of respondents to the 2008 Reach Advisors—ASTC study described information presented by science centers as “very trustworthy.” This trust is priceless and should be maintained. University partners will understand that it is a key reason that science museums are such ideal education outreach partners.

Evaluating the partnership. Just as the educational activities the partnership produces can be subjects of evaluation, so can the partnership itself. A true collaboration should be perceived by the partners as benefiting their own organizations as well as their intended audiences. Every so often it makes sense to deliberately reflect on and communicate about what is working and what could be improved, checking whether expectations on each side are being met. You don't want stresses to build up through misunderstanding or miscommunication. One way to facilitate this is to have an external evaluator conduct “stakeholder interviews” to help assess the health of the partnership and to collect new ideas for improving its effectiveness. Sometimes just a good review and brainstorming session over coffee and refreshments can stimulate new thinking and fresh approaches.

Signs of Success

The partners invite each other to join in on other proposals. They consult together on upcoming plans and invite one another to important meetings. They brag about their collaborative accomplishments. They provide testimonials. They think of new things to do together, and other ways to assist each other. They feel comfortable picking up the phone for a chat – or shooting off a quick email. They share great feedback from funders:

Our ongoing collaboration and partnership with The Franklin Institute has been both a pleasure and an inspiration for both myself and for numerous students, postdocs and other faculty in the MRSEC [NSF Materials Research Science and Engineering Center], and it's been beneficial to us on many levels. Our students, postdocs and faculty can see – and participate in – museum outreach from the inside. The museum staff is very knowledgeable about how to present science to children and families, how to develop a show, how to obtain feedback and assessment of the effectiveness of the shows, and also how to distribute the products of our collaborative efforts to a broader audience (including a network of other museums). As noted by a visiting NSF Advisory Committee, “The work with the Franklin Institute represents impressive national visibility.”

- Tom Mallouk, Pennsylvania State University

The Center demonstrated a very strong commitment to its educational and outreach mission, and should be commended for introducing a truly outstanding program in collaboration with the Boston Museum of Science. This program serves as a focal point of the Center's educational outreach activities by coupling the scientific expertise of the technical investigators at MIT and Harvard with the energetic and enthusiastic communicators of science and technology information at the Boston Museum. This program has the ability to expose a vast cross-section of people throughout the Boston area to the excitement of science and technology.

– Quote from NSF Review of the Harvard Nanoscale Science and Engineering Center, shared by Bob Westervelt

Best of all, you can see the success in the faces of people participating in your collaborative education outreach activities, and know you are making a difference.



References

Association of Science-Technology Centers, *2010 Science Center and Museum Statistics*. www.astc.org/about/pdf/Backgrounders/2010%20Science%20Center%20Statistics.pdf

RK&A (Randi Korn & Associates, Inc), *Volunteers Try Science (VoITS): Front-End Program Evaluation Executive Summary and Discussion*. New York Hall of Science. 2006.

Reach Advisors / ASTC (2008). *Preserve Past, Teach Present, Inspire Future: Presentation at ASTC Annual Meeting*, Oct. 18, 2008. James Chung and Susie Wilkening.

Additional references and resources are available in the online version of this guide at www.risepartnerguide.org



About the Author:

Carol Lynn Alpert led the development of the award-winning Current Science & Technology Center at the Museum of Science, Boston, and was one of the founders of the NISE Network. She develops and manages multiple long-term museum – research center partnerships dedicated to opening new avenues of engagement between scientists, engineers, innovators, K-12 and public audiences. In a former lifetime she produced history and science documentary television.

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