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Broadening and Deepening the Impact:
A Theoretical Framework for Partnerships
Between Science Museums and STEM Research Centers

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The requirement by the National Science Foundation (NSF) that research proposals include plans for "broader impact" activities to foster connections between Science, Technology, Engineering, and Math (STEM) research and service to society has been controversial since it was first introduced. A chief complaint is that the requirement diverts time and resources from the focus of research and toward activities for which researchers may not be well prepared. This paper describes the theoretical framework underlying a new strategy to pair NSF-funded nano research centers with science museums in order to achieve greater success in the broader impact mission, and to transform the perceived burden of the requirement into an opportunity to provide enhanced value to the constituencies of the partnering organizations, as well as to the larger community. This partnership approach is presented as a model that also can be applied to NSF-funded research centers in other STEM fields, and to non NSF-funded STEM research centers nevertheless looking to pursue broader impacts types of activities. The model also provides an opportunity to stretch the typical spectrum of broader impacts activities to include citizen engagement in science, technology and societal concerns.

Background: National Science Foundation Broader Impacts Criterion and Some Issues it Raises

Since 1997, the National Science Foundation (NSF) has required research proposals to address the "broader impacts" of research on science, education, and society (NSF 2009). Means of addressing these can include efforts to disseminate the results widely, to engage public and K–12 audiences, to broaden the participation of under-represented groups, to provide professional development to teachers and early career researchers, to enhance infrastructure for research and education, and to explore the potential societal benefits of research activities (NSF 2007). NSF proposal guidelines and subsequent "Dear Colleague" letters from various division directors indicate that efforts to address this "Broader Impacts Criterion" (BIC) will be reviewed as rigorously as the "Intellectual Merit" of the proposed research—its potential to significantly advance the scientific field.[1]

Discussion of the value and relevance of "BIC", as it has come to be known, has been occasionally contentious in the research community, as detailed in an excellent 2005 paper by J. B. Holbrook (Holbrook 2005). In August 2007, Holbrook and other science,

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technology, and society scholars gathered at a workshop at the Colorado Schools of Mines to review and analyze the controversies that have surrounded BIC since its inception. What were the goals of the original framers of BIC? How was progress toward those goals to be assessed? How much progress has been made? Are the original goals still relevant today? What changes, if any, should be made?

The Colorado workshop report reviews the conclusions of various independent critics and official BIC review committees that have described considerable confusion about BIC as well as resistance to it among the Science, Technology, Engineering, and Math (STEM) research community (Holbrook and Frodeman 2007). Critics question the somewhat uneven attention paid to BIC by current and perspective investigators, as well as lax peer review. NSF grant proposal peer review committees seldom include experts in education, outreach and the other service-oriented areas of broader impact, thus helping to perpetuate the cycle: inadequate BIC planning, inadequate assessment of BIC planning (Holbrook 2005).

The consternation felt by many STEM researchers regarding BIC was referenced from a widely-cited *AP News* article, which quoted MIT's Mildred Dresselhaus: "Many physicists feel they don't have the expertise to do outreach activities", she pointed out; and then added, "education and outreach should be encouraged, but shouldn't be a requirement for research funding." That requirement she described as "punitive," particularly for younger researchers (American Physical Society 2007).

Essentially Dresselhaus was saying that good researchers are not necessarily good educators. Who can argue with that? The notion that the BIC requirement is punitive for younger researchers*,* however, probably follows from the widely-accepted axiom that these participants must necessarily risk their tenure track progress when they divert attention to education and outreach. The stories of early career researchers discouraged from such "distractions" are legion. It is easy to argue that such attitudes must change, that education and service should count for something in the competition for tenure; however, it is also easy to forget that this is not simply an argument about values and moral prerogatives. Senior, even tenured, investigators must compete for limited grant funding to support the early career researchers in their laboratories. The pressure to produce scientific results, publish, mint new PhDs and gain additional collaborators in the competition for new grants creates a bottom-line incentive to keep efforts focused on the research. BIC would work better if it aligned better with the local demands of academia, or *vice versa*.

In the same *APS News* article, University of California at Davis faculty member Greg Miller spoke to the personal frustration of researchers, criticizing BIC for "encouraging scientists to do things that would actually slow down the research, such as having undergraduates work [alongside them] in a lab." This is a very interesting reproach, as it would apply most pointedly to NSF's popular Research for Undergraduates (REU) program, the underlying notion of which is that the best way to prepare as well as to motivate undergraduate students to continue their preparation for careers in science is to provide them with opportunities for authentic laboratory research experiences alongside seasoned mentors. One hears in Miller's understandable frustration the desire just to be left alone to focus on the research, pursue his passion, and make a contribution in the best way he knows how. Teaching, mentoring, academic committees, grant stewardship, outreach—all these aspects of a university researcher's life can feel like a tax on the limited resources of their time and attention.

How to Respond to BIC Criticism?

How to respond to the reluctance of some researchers to shoulder the burden of BIC, and to the logic of some of the arguments they present? How can attention to broader impacts and educational outreach produce a synergistic pay-off for early career researchers in their home institutions, rather than creating a stumbling block for them? Do we need to assist STEM researchers by offering them training in how to do BIC-style activities? Do we need to do a better job convincing them that broader impacts are something they should care about? Does NSF need to tighten up enforcement of BIC— applying greater rigor to its assessment and greater expertise on STEM proposal review panels and visiting committees? Or, in the opposite direction, should more laxity be allowed—fewer demands on researchers—perhaps moving BIC from the status of a mandatory requirement to that of a recommended option?

The Colorado workshop report notes that, in the past, NSF has tried to help puzzled researchers by offering conceptual clarifications and "how-to" guides that provide examples of BIC activities and some resources, on the theory that what researchers lack is knowledge and information (University of North Texas 2009). However, since these have not succeeded in resolving the issues, the report suggests, perhaps what the STEM research community needs most is help understanding the "why" of BIC, or "why scientists and engineers should become more sensitive of the possible broader impacts of their research" (Holbrook and Frodeman 2007). And perhaps the people best suited to communicate to STEM researchers the importance of engagement in broader impacts are "ROSTS" (academic researchers on science, technology, and society), such as philosophers and historians of science and technology, and scholars from science, technology and society (STS) and policy studies. According to this argument, ROSTS could be focusing some of their intellectual efforts alongside their STEM campus colleagues, teaming up with them to help expand the social, ethical, and historical vision of STEM students, and perhaps pursuing related research examining the potential societal implications of the center's science and engineering activities. ROSTS could thus help shoulder BIC burden and perhaps be given some share of the research budget to support these efforts; for if NSF insists that BIC efforts be taken seriously, and STEM researchers step in to help, budgeting implications will surely follow (Holbrook and Frodeman 2007).

Distinguishing Frames

It is interesting to step back for a moment and take a look at the different frames through which, on the one hand, the STEM researchers interviewed in the *APS News* article critiqued the practical implications of BIC, and, on the other hand, the way the Colorado discussants, coming predominantly from an STS perspective, approached them.

As cited above, Miller and Dresselhaus argued that the forced coupling of broader impacts activities to STEM research activities can often:

- slow down the progress of research;
- disproportionately burden early career researchers seeking tenure; and
- backfire by placing STEM researchers in education outreach roles for which they are unprepared.

In their comments, these researchers frame BIC as primarily a "reaching out more broadly" requirement, focused on education, engagement, and outreach.

In contrast, and perhaps not surprisingly, the Colorado discussants tend to frame BIC as a mandate to "explore broader impacts on society." Indeed, the Colorado workshop report raises the issue of whether "interpreting BIC only as 'the education and outreach criterion' tends toward 'advertising' for science and technology and away from BIC's potential to inspire critical reflection" (Holbrook and Frodeman 2007). This is not just the difference between reading the word "broad" as an adverb or an adjective; this gets to the heart of the debate over the meaning of BIC.

Ironically, a close textual examination of current NSF guidance on BIC reveals no explicit mention of sample activities with the goal of studying critical societal issues surrounding science and technology, except for the goal of increasing the diversity of investigators. The set of sample activities that comes closest to the concept of addressing societal impacts is the suggestion to pursue ways to address the "benefits of the proposed activity to society;" risks are not mentioned (NSF 2007). This selective wording underscores the positivistic outlook for science and technology that BIC was initially designed to support, alongside its STEM recruitment agenda, and its usefulness in winning continuing taxpayer support for basic research and for the agency that distributes those funds. The notion that STEM researchers are to be involved in critically examining both the positive and negative implications of proposed research projects—however important and useful that activity may be—is simply absent from current BIC guidelines. BIC does indeed seem to focus attention on education and outreach, diversity and infrastructure, and exploring only the benefits of research, rather than focusing attention on deepening the reflection and study of more controversial STS issues that may emerge. As a result, it is worth exploring compromise solutions that incorporate engagement in STS issues as part of the broader impacts training, education and outreach activities.

Making Choices

The need for addressing broader impacts—in its broadest definition, including societal implications both positive and negative—has perhaps never been greater. Americans face bewildering personal, political, economic, and ethical choices brought on by advancing technologies that have pushed beyond the boundaries of previous consensuses. Stem cell research, bioengineering, synthetic biology, nanotechnology, machine–human interfaces, renewed interest in nuclear power generation, investment in STEM education—all of these raise legal, environmental and ethical questions that US citizens must participate in addressing either explicitly or implicitly; for example, through voting or not voting, joining a national conversation or not joining one.

The question, however, remains: would increased academic study of the broader benefits and risks of new technologies help the electorate make better, more responsible decisions in these areas? Or, could education outreach—not fashioned as "advertising" for science, as the Colorado participants feared, but fashioned as broader citizen awareness, understanding, engagement, and deliberation—do more to engage a greater number of citizens in critical and informed reflection on new technologies? After all, as Maxine Singer (2009) pointed out in a recent *Science* op-ed piece, citing a 2006 Jon Miller research report, "only 40% of Americans accept the fact of biological evolution, and less than half of American adults can provide a minimal definition of DNA" (Miller, Scott, and Okamoto 2006). STS research aside, just the job of increasing scientific awareness, understanding, and engagement is huge, and perhaps necessary, before there can be greater efficacy with informed deliberation and consensus-building on the real STS issues facing us.

Add to this, the latest, most discouraging PISA statistics that Singer also cites: "American 15-year-olds ranked 24th out of 57 countries in science and 32nd in mathematics" (Mervis 2009). As Americans, we expect ourselves to do better, to be among the leading nations in STEM education, research, and innovation. And yet, we are failing. All around us we hear about the shortage in this country of qualified students pursuing advanced degrees in science and engineering, or even two-year degrees that would prepare them to fill the demand for competent laboratory technicians.

In this light, it is not surprising that the dominant interpretation of what constitutes BIC requirement activities points in the direction of STEM career pipeline support: increasing diversity, education, infrastructure, and outreach. Yet, this leads us to ask, how can we strengthen the BIC portfolio to educate, engage, and also advance the cause of critical reflection on the part of STEM researchers and public stakeholders?

Different Approaches

Do Researchers Need Convincing?

This was an idea that surfaced in the Colorado workshop, although many of us would argue that most researchers do understand the motivation behind BIC; at the very least, they understand that a better informed public is more likely to be more supportive of public investment in STEM research and to be more capable of reasonably assessing risks and benefits of new technologies. They also understand that their own efforts rely in part on maintaining a steady stream of inspired applicants to their undergraduate, graduate, and postdoctoral research programs, and that, indeed, increasing science literacy is a general good in a democratic society. They may not go so far as to fully accept some of the more encompassing notions of public engagement—that citizens ought to have greater voice in the direction of research, and that scientists themselves ought to be aware of the element of social construction in setting research goals and of the ways in which applications of their research may affect individuals, communities, and societies.

Although there are no statistics to cite, it does seem that most STEM researchers—at least those working in university environments—do accept the notion, whether explicitly a requirement or not, that they are teachers and mentors as well as investigators, and that some degree of service to the broader community that funds their work is desirable or at least justifiable. And would it not be a very good thing if all STEM post-secondary students were required to take at least one course, taught by ROSTS, that introduces them explicitly to the STS issues, to both deepen and broaden their social, ethical and contextual awareness?

Does NSF Need Convincing?

Holbrook (2005) describes several sincere efforts over the years to "beef up" program officer and reviewer attention to the assessment of BIC portfolios. Nevertheless, while BIC portfolio representatives regularly participate in presentations of research center work for site-visiting reviewers, few are the instances in which an STS or education outreach specialist has been invited to join a visiting NSF research center review panel to help review its BIC portfolio.[2] My own experience as a reader of preliminary STEM research and STEM education proposals indicates that very little attention is paid to broader impacts early in proposal development, and sometimes the budget has been divvied up before the BIC plan is conceived or potential BIC partners have been approached (Alpert 2008a).[3] If NSF continues to claim to be serious about BIC, it should probably renew whatever efforts it has made in the past to improve the critical review of these aspects of proposals. A more rigorous review would certainly motivate investigators to approach education and outreach less as acts of spontaneous charity and more as serious endeavors with measurable impacts. Proposals might then more often include reference to literature supporting the proposed broader impacts approach or to independent evaluation data indicating the value of comparable efforts.

Are there Enough "How-to" Resources on Education and Outreach Available to STEM Researchers?

A perusal of the resources cited in the Colorado workshop report reveals lean pickings, mostly one-time workshops that occurred at various intervals in the past (University of North Texas 2009). (The Nanoscale Informal Science Education Network [NISE Net] has recently added one new education outreach resource to the list, "Bringing Nano to the Public." which provides some guidelines to STEM researchers, not necessarily confined to outreach about nano research [Crone 2006].) However, even when provided with "how-to" resources, researchers still must invest in the effort to learn from them and to figure out how to apply them effectively in their own environments, and how to evaluate their impact. While helpful, this "how-to" approach alone cannot adequately address the time, energy, talent, and preparatory barriers raised by the researchers cited in *AP News*. Informal science education (ISE) and engagement are areas of specialized professional training. Researchers can often learn quickly and succeed with the help of written guides or professional development experiences, but they can also struggle and fail. Some research centers are fortunate to have dedicated education and outreach staff, who assist with REU, Research Experience for Teachers (RET), and Graduate Teaching Fellows in K-12 Education (GK-12), although these staff are typically less experienced with broader audiences, beyond providing on-campus lectures open to the public. The university campus is not a particularly public-friendly space, however, and university researchers and their staff do not often have easy access to more appropriate audiences and venues for broader public engagement and outreach.

Seeking a New Model

This author's conclusion is that we need a new model for addressing broader impacts—one that pairs STEM researchers with education and outreach experts, appropriate audiences and venues, and skilled facilitators of STS discussions, including university-based ROSTS.

The Research Center–Informal Science Education Partnership Model

The RISE model recognizes that researchers are not necessarily prepared to be the sole architects and deliverers of education outreach and public engagement experiences. Here, they have the opportunity to collaborate with ISE professionals in designing and carrying out those experiences off campus; in addition, they also have the opportunity to gain new skills in these areas should they choose to do so. If, instead, they choose a route of minimal personal participation, the ISE collaboration can relieve them of the organizational and planning responsibilities that some scientists say distract too much from their research and teaching and perhaps essential tenure-track activities. The ISE partner can provide structure, support, and expertise that leverages what the researchers have to offer and makes the public engagement process more effective and enjoyable for everyone.

The idea of research scientists associating with science museums and other ISE efforts is not new. Indeed, some of these institutions were indeed founded by scientists; a well-known example being San Francisco's Exploratorium, founded by Frank Oppenheimer in 1969. Scientist involvement in the development of museum exhibits and programs goes way back, to a time when natural history museums were still predominantly research institutions. (And some continue in this dual role today; for example, the American Museum of Natural History.) Researchers also have, on their own, sought out science museums as broader impacts partners, usually by offering to give lectures there on their research. Others volunteer, as individuals, giving demonstrations and participating in research fairs. A science professional organization, the Materials Research Society (MRS), went so far as to organize and develop funding for a large (and successful) traveling exhibit on materials science, "Strange Matter" (MRS 2003). The National Institutes of Health's National Center for Research Resources Science Education Partnership Award program (SEPA 2009) encourages proposals from science museums partnering with university researchers for educational outreach.

However, the NISE Net's RISE initiative is the first program specifically dedicated to fostering one-on-one institutional, public engagement partnerships between STEM research centers and science museums across the nation. It is an explicit goal of the Network that a dozen of its member science museums will develop dedicated institutional partnerships with research centers, and that more than 100 will develop at least occasional collaborations that may grow into more substantial partnerships. These partnerships currently range from fairly casual volunteer collaborations around annual NanoDays activities—to fairly substantial annual sub-awards from NSF Nanoscale Science and Engineering Centers that support science museum staff and a wide range of complementary broader impacts activities. NanoDays activities have been held at more than 200 sites across the country (NISE Net 2009c). Many thousands have been reached through these activities and events. According to the May 2009 external evaluation report from Inverness Research, the NISE Net has had marked success in connecting nano researchers with informal science educators and connecting nano research centers with ISE institutions (St John et al. 2009).

Much of this success is due to the recognition by research center leaders that the science museum partner can assist them in achieving their broader impacts public engagement goals. Bob Westervelt, principal investigator of the Harvard-based Nanoscale Science and Engineering Center, emphasized the benefit of that expertise, in this comment:

> As my colleague Bert Halperin and I began work on a proposal for an NSF-funded Nanoscale Science and Engineering Center (NSEC) at Harvard, it was clear that we must actively engage the public. Many academic researchers would like to inform the public about nanoscience, but don't know how to do it. Science museums, on the other hand, are keen to get people's attention, show them what is happening, and invite them to think about the big ideas. A collaboration with a science museum would be an excellent way to involve the public with our research work. (Westervelt 2008, 8)

Speaking at the 2007 Nanotech Symposium for Educators and Journalists at the Museum of Science, Boston, Ahmed Busnaina, principal investigator of the NSF Center for High-rate Nanomanufacturing, headquartered at Northeastern University, also focused on the expertise on science museum staff:

> 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 that the public can understand … they're like our segue to the public, they're 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 scientists or students that have science background. (Busnaina 2007)

Science museum partnerships have accrued some unexpected benefits to their research center partners. These have included enthusiastic NSF site visit committee reviews of their education/outreach portfolios, a higher community profile, better connections to secondary school and community college educators, enhanced recruitment for their RET and REU programs, and, most recently, professional development programs for their graduate students in science communication, conducted by museum staff.

The decision to collaborate with science museums also seems to reflect a growing understanding on the part of researchers that public engagement works best on a two-way street. For example, Westervelt noted:

> The collaboration continues to benefit all parties. Graduate students who work at the museum connect with the public at an early stage and learn how to integrate their plans and careers with issues of public importance. Museum visitors are drawn into engagement with advances that excite researchers, such as carbon nanotubes and bucky balls, and with larger questions, such as “good” vs. “bad” science. They can see why academic scientists find nanoscience so involving—and can raise any concerns they may have about the new technologies. (2008, 8)

This insight underscores the point that science museums are not merely one-way conduits to help address the public’s science literacy deficits, nor are they merely “advertisers for science,” touting technological solutions to every problem. Science museums are places where scientists and other citizens can explore and deliberate on STS issues together. Almost all NISE Net exhibits, programs, and media include STS aspects of nano research (NISE Net 2009a). In addition, the Network has fostered the development of public forum models on nanotechnology and privacy, public health, the environment, and other controversial issues (NISE Net 2009b). These forums have been held at science museums in Portland, Oregon, Durham, Fort Worth, St Paul, and Boston. The Museum of Science in Boston collaborated with the City of Cambridge’s Department of Public Health in developing one such forum in 2008, shortly after the city began reviewing its own policy toward local nanomanufacturing and research activities (Museum of Science 2008). As Susanna Priest wrote in the spring 2009 issue of *Museums and Social Issues*, science museums “have considerable social capital (in the form of popular trust) available to invest in public engagement endeavors […] [t]hey are still seen as reasonably neutral arbiters of truth” (Priest 2009, 59–60).

The RISE initiative also explicitly includes the notion of fostering in early career researchers lifelong interest and practical skills in public engagement. The team is developing several types of training programs for undergraduates, graduate students, and postdoctoral students, in collaboration with local research centers. These include ISE internships, science communication workshops, and hands-on, demo-based workshops with follow-on practice with real audiences. These efforts not only assist the young researchers in their career efforts, by improving their cross-disciplinary science communication skills; they also introduce the students to inquiry-based teaching and engagement models and put them in touch with community-based questions and concerns.

To support the involvement of individual scientists, not necessarily associated with research centers, the NISE Net has also formed a network-to-network partnership with the MRS. The MRS is a NISE Net sub-awardee, and its scope of work includes providing infrastructure and encouragement for MRS members to be involved locally on a volunteer basis. This infrastructure allows individual scientists to leverage the resources of the NISE Net and of the MRS to participate in broader impacts service and activities, thereby helping to satisfying their own BIC grant responsibilities as well as contributing to the coordinated national effort (MRS NISE Net 2009). Many of the education outreach directors associated with NSF Materials Research Science and Engineering Centers and NSF Nanoscale Science and Engineering Centers have also become involved in the NISE Net, forming a critical cultural bridge between universities and science museums and serving as coordinators on the university side.

Implications beyond Nano: The National Nanotechnology Initiative Pioneers a Broader Impacts Spectrum Approach

The US National Nanotechnology Initiative (NNI), developed by the Office of Science and Technology Policy under the leadership of Mihail Roco, is the first national science and technology initiative to plan a comprehensive R&D roadmap that includes explicitly designated funding for academic research and practice in the widest spectrum of the broader impacts portfolio.[4] (While the National Institutes of Health's Human Genome Project came to include an Ethics, Legal, and Social Implications program, it was reportedly added only after an off-the-cuff remark made by founding director James D. Watson at the press conference launch of the Human Genome Initiative in 1988, and it was not designed to be integrated into the policy-making structure of the Human Genome Project as a whole.[5]) So, for STEM researchers, ROSTS, and education and outreach specialists alike, the carefully laid out NNI roadmap is of major significance. The roadmap includes plans for incorporating nanotech research in many areas of science and engineering, overseen by the respective federal science agencies, but it also includes distinctly funded centers and networks that are to tackle many key elements of a broad-spectrum BIC portfolio. These include the Network for Nanotechnology in Society, charged with addressing a broad STS agenda, and the Center for the Environmental Implications of NanoTechnology, charged with tackling portions of the environmental agenda, alongside other centers focusing on toxicology and nano-bio issues funded by NSF, the Environmental Protection Agency, and the National Institute for Standards and Technology. Whether enough is being done in these areas is still a matter of considerable disagreement, but it is nevertheless significant that the nation's highest science and technology policy group, the Office of Science and Technology Policy, invited ROSTS to specifically apply their knowledge and expertise to a major science and technology initiative as it is developing.[6]

Further along the NNI broader impacts spectrum approach, the National Nanotechnology Infrastructure Network and the Network for Computational Nanotechnology provide infrastructure, training and support. K–12 education development has been the province of the National Center for Learning and Teaching in Nanoscale Science and Engineering.[7]

To enhance education and outreach—the more traditional broader impacts activities—the NSF, working within the NNI roadmap, called for the development of a Nanoscale Informal Science Education Network. That effort was launched in 2005, after a review of competitive proposals from several science museum-led teams. It was an unprecedented investment by NSF into the science museum community, a five-year, $20 million commitment, with potential for renewal. The funding came from among several NSF directorates sponsoring nanoscale research as well as from the education and human resources directorate, which also administers the funding.

The program solicitation for the NISE Net was specifically directed at science museums, and the charge was to:

> … foster public awareness and understanding of nanoscale science and engineering through the establishment of a Network, a national infrastructure, that links science museums, and other informal science education organizations with nanoscale science and engineering research organizations. (NSF 2005).

The architects of the NNI seemed to have recognized that the opportunity for addressing broader impacts through science museums and other ISE organizations is immense. Indeed, the Association of Science–Technology Centers (ASTC 2006) reported that over 70 million people visited its member institutions in 2006 alone. In the 2006 National Science Board *Science and Engineering Indicators*, Jon Miller cited a 2001 figure that 30% of Americans report visiting a science museum within the past year, and more recent surveys show little change (Miller 2006). Beyond their front doors, science museums are now cablecasting, podcasting, publishing on the World Wide Web, running public forums offsite and conducting traveling programs in school classrooms—they are indeed becoming the social and cultural institutions most associated with connecting the research community to the consumers, funders, and stakeholders of science and engineering research within the larger, national community.

The NISE Net—headquartered at the Museum of Science, Boston, and including the Exploratorium and the Science Museum of Minnesota as core partners, along with other institutional collaborators and sub-awardees such as the ASTC and the MRS—stresses the need to build the capacity of science museums to address this challenging area of science education (cannot see the nanoscale; cannot touch it), as well as the need to experiment with innovative forms of education and engagement. Very significantly, the NISE Net partners chose to add to the charge given to them by NSF the notion of engaging citizens in dialogue and deliberation over the societal implications of nanotechnology, and they have reached out to partner with university STS researchers and with organizations like the Woodrow Wilson Center's Project on Nanotechnology to access their expertise in defining and researching these larger issues. NISE Net exhibits, programs and media typically include reference to—or content concerning—broader STS issues (NISE Net 2009a).

While NISE Net collaborators are busy developing replicable exhibits, programs, media, visualization tools, designs for public forums, and capacity-building professional development experiences, they are also concentrating on building a network, involving increasing numbers of ISE organizations in developing and delivering nano ISE experiences, reaching out to minority communities, and forming connections with nano and materials research centers and their investigators. The RISE initiative is a part of this larger effort, reaching out both to the university research community and to the science museum community with advice on forming effective partnerships, a menu of partnership models, tools for public engagement, and consulting services for finding appropriate partners (Alpert 2008b). These partners, mostly regionally based, will be able to make use of the mostly open-source educational and professional development tools being developed by the NISE Net, adapting them for local use, hacking them, improving them, and re-submitting them—thereby contributing their own innovations to the broader networked community.

Conclusion

The RISE initiative is important to long-term NISE Net strategic planning: building a network of research center–ISE partners that can support, renew, and sustain engagement between the nano research community and the community at large on an ongoing basis. The notion here is that by seeding and cultivating regional collaborations between researchers and ISE institutions, the ideal of public engagement with research is more likely to become a regularly practiced reality, one that can extend beyond nanoscale research to all fields of scientific endeavor.

With NSF providing support for NISE Net growth and development, the broader impacts initiatives of nano and materials science research centers are fortified locally and leveraged to enrich the larger community with new ideas and practices for greater engagement and impact. Yet, once direct NSF support has run its course, will other funders step in to help maintain the infrastructural backbone of the NISE Net? Will the Network diversify successfully to other fields of scientific endeavor? Or will research centers once again be left to their own devices to pursue their broader impacts efforts? This will prove a critical turning point, where the newly engrained practice of partnering with ISE organizations as education, outreach, and STS engagement collaborators will put to the test. Fortunately, one option for supporting such enhanced broader impacts partnerships—through research center sub-awards—will still exist.

Notes

[1] See the *NSF grant proposal guide* and *NSF merit review Broader Impacts Criterion* documents cited above as well as the NSF "Dear Colleagues" letters, such as NSF 07046 and NSF 08062. Available from www.nsf.gov.

[2] The author was invited to be part of a site visit panel for the review of a large NSF Science and Technology Center in 2008; this was probably due to the fact that I had recently given a talk on effective partnerships for education outreach at an NSF meeting of research directors and program officers; I know of only one other similar example.

[3] As recounted in the source cited, it is not unusual for science museums to receive calls for letters of support for a STEM research proposal, due within a day or two, and promising some kind of lecture or outreach event, with no budget allocated and little opportunity for discussion as to what might be the most effective format or venue (Crone 2006).

[4] See *The National Nanotechnology Initiative Strategic Plan*, developed by the Nanoscale Science, Engineering, and Technology Subcommittee of the Committee on Technology of the National Science and Technology Council (2004), and *The National Nanotechnology Initiative at five years: Assessment and recommendations* (President's Council of Advisors on Science and Technology 2005).

[5] Email communication from J. B. Holbrook, 18 September 2009: "… ELSI was a kind of accident (Watson declared that they planned to devote 3–5% of the Human Genome Project budget to the project's ethical, legal, and societal aspects at a press conference when he was pressed by reporters). So, unlike NNI, ELSI wasn't pre-planned." For an account of this incident, see Marshall (1996). For a discussion of distinctions between the Ethics, Legal, and Social Implications program and plans for the NNI, see Fisher (2005).

[6] The Wilson Center's Project on Emerging Nanotechnologies is a good place to start investigating these controversies. Available from www.nanotechproject.org.

[7] See www.nano.gov for a lay-out of all the current centers and networks.

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