PROJECT SUMMARY

Overview:

The Museum of Science seeks an Innovations in Development award for a project aimed at building capacity among institutions of informal science education (ISE) to develop and implement multi-site public engagement with science (MSPES) activities in partnership with scientists working in the field of synthetic biology (synbio). In the first year of the project, materials will be developed collaboratively by participants from eight ISE sites, in partnership with local synbio scientists, with support from a central team of ISE professionals, synbio researchers experienced in public outreach, and experts on public engagement, science and society, and science communication. Materials tested at the eight pilot sites in year 1, will be revised and packaged into a kit like the kits developed by the Nanoscale Informal Science Education Network (NISE Net) for annual NanoDays events. The MSPES project will leverage work done by the NISE Net to disseminate 200 SynBio Kits to sites across the U.S. and help recipients to incorporate public engagement with science (PES) activities about synbio into their educational programs. In addition to summative evaluation to identify project outcomes, an internal team of evaluators will develop approaches to evaluating PES activities, which have intended outcomes for both public and scientist participation that are different from those of most ISE work that is firmly base on "public understanding of science" goals. Finally, all materials developed to support public engagement with synbio will be revised and posted online for open access to all who want to use them in the future. In addition, a guide to developing single-site and multi-site PES activities on other topics will be produced, shared online, and presented in publications and at professional meetings of informal educators and scientists.

Intellectual Merit :

The MSPES project builds upon the work of several prior NSF-funded projects including a pathways grant (1010831) that explored the extent to which ISE organizations are implementing PES, as differentiated from "public understanding of science" in the Center for the Advancement of Informal Science Education 2009 report Many Experts, Many Audiences: Public Engagement with Science. Despite calls from social scientists and science policy experts for a decade, our prior work found that PES strategies are far from fully implemented in the work of ISE organizations. At a workshop held as part of the pathways project, 55 ISE professionals interested in PES outlined nine priority areas for further development of PES in ISE. The proposed MSPES project will address several of those priorities. In addition to the extensive experience the Museum of Science has with PES, it will also bring to the project its experience in leading and managing the huge NISE Net project (0940143) with many subawardees and hundreds of partners. Scientists with particular interest in public engagement from the NSF-funded Synthetic Biology Engineering Research Center (0540879) and public engagement leaders at the American Association for the Advancement of Science bring content expertise and a commitment to support scientists in adopting PES approaches to communicating with the public, in addition to the one-way from expert to public communication approaches that are still widely prevalent today. Kit development experts from the Science Museum of Minnesota and Ithaca’s Sciencenter will turn prototype activities into kit components building upon the NISE Net’s highly regarded and successful NanoDays kits. Additional support from experts in social and political sciences, and in engaging diverse audiences, as well as from pilot site participants and NISE Net regional hub leaders, will ensure not only the development of new knowledge in this project but also its wide dissemination.

Broader Impacts :

The public will benefit from the MSPES project in several ways. The project will create materials, activities, and increased capacities among ISE organizations and scientists to engage the public in learning about synthetic biology-a topic about which a Presidential Commission has said that public deliberation is particularly valuable. It will also further develop PES in both ISE and science communities. Broader implementation of PES will help members of the public discover ways to engage with scientists to consider impacts and policies related to emerging technologies, feel a connection to the enterprises of scientific research and technological development, share their views, and even contribute to efforts to maximize their benefits to society.

Multi-Site Public Engagement with Science (MSPES) – Synthetic Biology

A. Project Rationale

The aim of this Innovations in Development project is to build upon the everyday museum interactions with visitors, based on the familiar "public understanding of science" model of one-way flow of knowledge from experts to the public, to also include multi-directional "public engagement with science" (PES) interactions in which publics and experts both learn from each other, using the topic of synthetic biology as the content focus. Synthetic biology is a particularly appropriate topic because it is an emerging field with significant future promise that is unfamiliar to various publics and ISE educators, has significant societal and ethical implications to be explored, and has leaders in the field who are supportive of public engagement activities. The specific focus of this project is to develop innovative resources, practices, and processes to build the capacity of the field to use PES activities to extend STEM learning about science, technology, and their societal implications through public and scientist dialogue about synthetic biology, in ways that can be transferred to other topics in the future.

In Year 1 of the project, Museum of Science (MOS) staff with expertise in PES will work with leaders in PES at the American Association for the Advancement of Science (AAAS), leaders of the Synthetic Biology Engineering Research Center (Synberc) from MIT and UC-Berkeley, and informal education professionals at 12 science museums in partnership with local research scientists, to develop public engagement activities, materials, and tools that will be implemented and evaluated at eight sites across the U.S. Educators at the Science Museum of Minnesota and the Sciencenter in Ithaca will bring additional expertise as the project leverages the infrastructure and capacity-building work done by the NSF-funded Nanoscale Informal Science Education Network (NISE Net) over the past decade to expand the reach of the project to 200 sites nationally in Year 2.

Why is public engagement with science needed, and what do we mean by "public engagement?"
A significant division exists between scientific and technical specialists and the wider public. Although technical knowledge is arguably needed by everyone, now more than ever, experts involved in producing such scientific knowledge are often isolated from its complex, social contexts and implications (Fischer 2000, Irwin 1995) and the public lacks the technical understanding of today's abstract and complex scientific research (Pauwels, 2013). This disconnect marks a missed opportunity according to scholars of risk, who assert that enlivened public engagement with scientific and technical decision-making is vital for managing long-term risks and realizing the benefits of new discoveries and technologies (Funtowicz and Ravetz, 1992; Turnpenny, Jones, & Lorenzoni, 2011). Daniel Yankelovich (2003) argued that "to break out of the specialist box, scientists need techniques (such as specialized forms of dialogue) for framing policy options that give the proper weight to their scientific content in relation to nonscientific variables" with a goal toward reaching sound public judgment on scientific issues.

Over the past decade, many in the science communication and public policy arena have argued that to do this, there is a need to engage the public in multi-directional dialogue about science-related societal and public policy issues in a way that allows scientists to learn from the public as well as the public to learn from the scientists (Borchelt & Hudson, 2008; Jasanoff, 2003; Barben, Fisher, Selin, & Guston, 2008).

> *We need to move beyond what too often has been seen as a paternalistic stance. We need to engage the public in a more open and honest bidirectional dialogue about science and technology and their products, including not only their benefits but also their limits, perils, and pitfalls.* (Leshner, 2003)

ISE professionals are uniquely situated to inspire and mediate the types of interactions between scientists and publics that are critically needed today. Science centers already engage scientists as advisors and speakers, partner with them in outreach activities of all kinds, and provide training and opportunities to practice science communication skills (PoPNet, NISE Net). ISE institutions are skilled at communicating science to the public and are seen as trusted conveyors of controversial scientific topics (Leiserowitz et al, 2010). Thus, they are well positioned to facilitate conversations among diverse stakeholders about socio-scientific issues – societal issues that are informed by science. Despite this potential, ISE programming that explores the full benefits of PES is still limited (Kollmann, Bell, Iacovelli, & Beyer, 2012). The proposed Multi-Site Public Engagement with Science (MSPES) project will help science centers become increasingly skilled at PES–specifically at designing experiences and convening conversations that engage scientists and the public in multi-directional dialogue about current or anticipated socio-scientific issues.

The potential for ISE institutions to facilitate PES was documented in 2009, in an inquiry group report commissioned by the Center for the Advancement of Informal Science Education (CAISE) with support from NSF (DRL-0638981). The report characterized PES activities as follows:

> *Public Engagement with Science (PES) is usually presented as a "dialogue" or "participation" model in which publics and scientists both benefit from listening to and learning from one another…. premised on the assumption that both publics and scientists have expertise, valuable perspectives, and knowledge to contribute to the development of science and its application in society* (McCallie et al., 2009).

The report contrasts PES with the dominant paradigm in the ISE community, commonly referred to as "public understanding of science" (PUS), which focuses on one-way transmission of scientific knowledge from the scientific community to individuals in society, sometimes with the ISE organization as an intermediary. Proponents of PES note that while some understanding of science and technology is required for societal decision-making, other factors are also important, including consideration of social values and personal experience. Therefore there is a need for people with diverse backgrounds, sources of expertise, and interests to contribute to the discussion (Kolsto, 2006; McCallie et al., 2007).

In order to create effective multi-directional conversations, *scientists* may need the most support. Despite a growing interest in civic engagement, scholars of science & technology studies remind us that scientists and technical experts can be challenged to find meaningful roles in addressing socially complex issues (Nowotny 2003). Furthermore, several past studies in the US and the UK have found that most scientists blame public ignorance of science for flawed policy preferences and political choices. They believe the public is inadequately informed about science topics and that, except for a small minority, the public is not interested in becoming more knowledgeable. Most scientists favor one-way communication with the public, viewing engagement primarily as disseminating scientific information, not two-way dialogue and public participation in decisions. In UK data, only 12% of scientists indicated that engagement meant listening to or attempting to understand the views of the public (Besley & Nisbet, 2013).

Therefore, a key feature of the MSPES project will be to involve scientists in developing and implementing PES events, having multi-directional dialogue with diverse publics during the events, understanding the motivations for, and benefits of participating in PES and disseminating outcomes to publics and their own research communities. The AAAS has suggested scientists in the synthetic biology community a good place to start because of their interest in public engagement. Museums and other ISE institutions have a long history of working at the boundary between scientists and publics. Educational activities grounded in Public Understanding of Science remain an important part of the work of ISE, but with added support for effectively facilitating Public Engagement with Science, the ISE field can help meet a growing need for dialogue on crucial societal issues where public interest and emerging science and technology present exciting new possibilities and an uncertain future.

Results of Relevant Prior Work

Despite the potential societal benefits of PES, science museums and related ISE organizations have implemented only a few educational program activities that fully support PES goals.

DRL 1010831, $247,355, 9/1/2010 – 2/28/2013, *Dimensions of Public Engagement with Science*, Lawrence Bell, PI; Elizabeth Kunz Kollmann, Co-PI.

Intellectual Merit: The MOS conducted a survey in 2011 to explore the prevalence of PES activities in the work of the ISE community. Over 150 organizations submitted descriptions of 201 projects–ranging in format from art and theater to festivals to on-site research. In *Many Experts, Many Audiences: Public Engagement with Science*, McCallie, et al., (2009) developed three dimensions across which programs and activities could be identified as supportive of a multi-directional learning model, as shown in Table 1.

Table 1. Three PUS–PES Dimensions (Adapted from McCallie et al. 2009)

	Content focus of the project	Audience involvement in the project	Expert involvement in the project
Public Understanding of Science ↕	Understanding of the natural and human-made world	Learning from watching, listening, and viewing lectures, media, exhibits, etc.	Experts serve as advisors and provide input to the project
	The nature of the scientific/ engineering process or enterprise	Asking questions of experts and interactive inquiry learning	Experts actively present their expertise to the public
	Societal and environmental impacts and implications of STEM	Consultation and sharing views and knowledge among participants and experts	Experts work to become skilled and informed communicators
	Personal, community, and societal values related to STEM applications	Deliberation with other participants and group problem solving	Experts welcome and value participant inputs and direction
Public Engagement with Science	Institutional priority or public policy change related to STEM	Participants produce recommendations or reports	Experts act on participant input and direction

The 2011 survey asked respondents to self-score their projects based on these three dimensions, across which programs and activities could be identified as more or less supportive of PES. Within the submissions four distinct clusters of activities were found that differed in the extent to which they included PES supportive elements (Kollmann et al., 2012). Analysis showed that even in this survey, which sought to find activities that step beyond the one-way transmission of knowledge associated with public understanding of science, none of the clusters included elements strongly supportive of PES across all three dimensions. However, dialogue programs pushed the furthest toward PES by supporting content related to institutional priorities or public policy, involving participants in sharing views and problem solving, and including experts who welcomed and valued participant input and direction.

If we look at the mean prevalence of PES supportive characteristics along the three dimensions for all 201 case summaries submitted, we find PUS supportive characteristics to be more prevalent than PES supportive characteristics, with expert participation falling off soonest, public participation next, and content falling off more slowly as we move toward characteristics more supportive of PES (Figure 1).

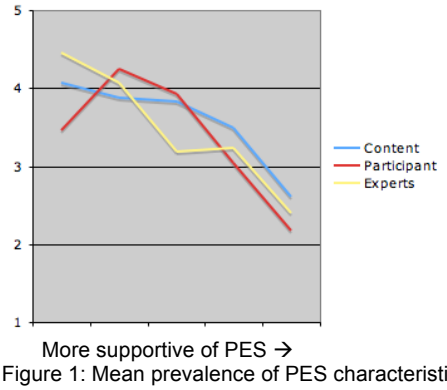


Figure 1: Mean prevalence of PES characteristics

Analysis of the case summary surveys found that most commonly, projects had public awareness, knowledge, or understanding goals; and public engagement or interest goals to a lesser extent; but projects were much less likely to include goals for the scientists' involvement (Iacovelli, Beyer, & Kollmann, 2012). Despite high levels of interest in PES in the ISE community indicated by the responses to this survey, and field-wide goals such as those in the Science Centre World Congress *Toronto Declaration* (2008) ("We will actively seek out issues related to science and society where voices of citizens should be heard and ensure that dialogue occurs"), very little PES was happening in U.S. science museums as of 2011.

After data collection and preliminary analyses, we invited 55 of those who submitted case summaries to attend a workshop in Boston to explore the findings, share ideas, and develop thoughts about strategic directions for PES in ISE. Recognizing the paucity of fully-realized PES in the field and realizing that they had little knowledge about the PES work of others, participants showed clear interest in sharing and knowing more, and described nine priority areas for further development of PES in ISE (Bell & Kollmann, 2011), summarized in Table 2.

Table 2. Strategic Priorities for Advancement of PES in the ISE field

1. Develop a philosophy of practice that embeds informal science institutions in their communities to be active participants in community civic issues, because of their capabilities to convene and facilitate.
2. Develop methods to keep public engagement going after engagement events, through such tools as social media, online activities, collaborations, community relevance, stakeholder communities, and linkages to civic issues.
3. Build the ISE infrastructure to respond to issues as they arise by connecting practitioners, building best practices, expanding/generalizing current efforts, connecting to existing networks, and providing resources, tools, and guides.
4. Develop a community of practice to investigate, articulate, and acknowledge the diverse goals and motivations for developing PES activities, and to develop an evaluation framework that can handle the complexity of PES.
5. Explore common goals for public and scientist/expert participation in PES, research actual goals of past or current participants, and develop an understanding of benefits to share with all.
6. Seek strategies for PES for hard-to-reach, non-traditional audiences, matching topics with audience interest and need, and developing delivery strategies that work for audiences not now engaged.
7. Develop methods for augmenting current and future exhibits and programs with PES components and strategies to cost effectively leverage existing resources and reach larger numbers of people with PES.
8. Develop funding strategies for PES, potential audience-financed models as well as identifying corporations, foundations or other organizations with interest in the societal benefits of PES that might provide funding.
9. Explore ways to dissemination PES strategies, products, resources, tools, technologies, motivational values, and embedment strategies with traveling programs, showcases; and a core task force to develop and disseminate.

Broader Impacts. Data from pre/post surveys and a survey sent three months after the workshop showed that the *Dimensions of PES* project built knowledge and interest in PES among survey and workshop participants. Participants showed a broader understanding of PES and of current PES projects, interest in adding PES to ongoing and future work, and in collaborating with each other, and said they were likely

to implement PES activities at their institutions because of the workshop. At the three-month check-point in 2011, half of the participants said they were working on or had submitted a funding proposal since the workshop in part due to or influenced by their participation.

The *Dimensions of PES* project also provided the basis for taking the first step in organizing multi-site PES activities through a December 8-9, 2011 *Workshop to Explore Engaging Broader Publics in Conversations About Assessment of the Societal Implications of New and Emerging Directions in Science and Technology* (DRL 1120436, Lawrence Bell). Partners from the ECAST Network (Expert and Citizen Assessment of Science and Technology) at Arizona State University, the Woodrow Wilson International Center for Scholars, the Loka Institute, Sciencecheerleader.com, and the Museum of Science helped develop ideas for engaging the public in deliberations about the societal implications of science and technology. The workshop focused on a near-term opportunity to explore new approaches in connection with the *World-Wide Views on Biodiversity* global citizen consultation, which was subsequently held at 32 sites around the world on September 15, 2012. ECAST coordinated U.S. participation, which included formal citizen consultations at four sites in the U.S., development of a discussion question specifically for U.S. participants in addition to the world-wide questions, and dissemination to scientist, ISE, public, and policy audiences in the U.S. through presentations, reports, and development and dissemination of a range of ISE activities envisioned at the workshop. The ECAST group learned that it could successfully coordinate activities across multiple sites and that the workshop itself stimulated renewed interest in PES.

DRL 0532536, $19,999,169, (10/1/05-9/30/11); **DRL 0940143**, $16,967,068 to date, (9/1/10-8/30/15); *Nanoscale Informal Science Education Network*, Lawrence Bell (PI); Paul Martin, Rob Semper (Co-PIs).

Intellectual Merit. The Museum of Science, in partnership with the Science Museum of Minnesota and the Exploratorium, developed a national community of researchers and informal science educators dedicated to fostering public awareness, engagement, and understanding of nanoscale science, engineering, and technology. With a total of 18 subawardees playing a wide range of roles during the eight years since its launch, the project has created a network of approximately 500 participant institutions, and an online catalog of 318 entries in categories called programs and activities, forums, exhibits, tools and guides, and media, as well as over 250 evaluation reports. Educational materials developed by NISE Net are scientist reviewed, peer reviewed, and visitor evaluated and include all the resources needed that can be shared online and information about where to acquire the physical materials.

The principal vehicle for disseminating educational materials and professional development resources of the NISE Net has been through development and distribution of ~200 NanoDays kits annually designed to be used during a one week NanoDays event period in the spring when NISE Net reaches approximately 500,000 members of the public mostly in family groups. Nearly all kit recipients report, however, that they use NanoDays kit materials throughout the year for a wide range of education programming for audiences of all ages. *A Study of Communication in the Nanoscale Informal Science Education Network* (Alexander et al., 2012) found that the NanoDays kit makes complex topics like nanotechnology accessible to museum professionals and the public, and that the quality of the kit conveys the professionalism of the Network and the importance of nano. In 2012 NISE Net worked with members of the Center for Nanotechnology in Society, who will also work with us in this MSPES project, to develop informal educational activities to engage the public in consideration of the societal implications of nanotechnology.

Broader Impacts. In addition to providing informal educational material about nanoscale science, engineering, and technology to informal science educators and university outreach coordinators, NISE Net has advanced a wide range of best practices or initiated new practices within these communities through professional development activities and published tools and guides. Knowledge and skills advanced in this way have included: science communication skills for early career scientists, universal design of exhibits and programs, societal and ethical implications content, public engagement and dialogue strategies, team based inquiry as a formative evaluation tool, forming and sustaining partnerships between research centers and ISE organizations, and designing for bilingual audiences. Network members report using program development templates, exhibit design models, evaluation forms, and other resources produced and distributed by the NISE Net for the development of their own educational materials on a wide range of topics.

Synthetic Biology in personal, cultural, and societal frameworks

The STEM content area that will be the focus of this project is synthetic biology (synbio). This rapidly

advancing interdisciplinary field involves the design and construction of new biological entities and systems to meet specific goals, or the redesign or enhancement of existing biological systems. Synbio presents revolutionary potential for applications such as energy, clean water, medicine, and materials science, through the creation of engineered organisms. Like other emerging technologies, synbio has the potential to have major future impacts on society.

> *The vision of synthetic biologists is a future in which humans engage in the large-scale design and creation of new life forms that are exquisitely tailored for human purposes. The…extensive design and manufacture of living things from virtual genetic sequences blurs the line between machine and organism, life and nonlife, and the natural and the artificial and therefore transforms the relationship between humankind and nature in ways that are exciting to some people but troubling for others*. (Pauwels, 2013)

The nature and societal implications of synbio raise profound questions on topics such as intellectual freedom, oversight, and responsibility that science cannot answer alone, but are best addressed through the participation and input from diverse publics (Bennet, Gilman, Stavrianakis, & Rainbow, 2009).

Synthetic biology is a good topic for PES because despite its potential profound impacts on society, public awareness of these impacts is low, and it raises challenging socio-scientific issues. Furthermore, the sybio research community is interested in public engagement (DOE, 2010; Parens et al, 2009). Two sessions at the 2013 AAAS annual meeting featured MSPES advisors from the synbio community discussing the need for scientist and public dialogue about synthetic biology. Additionally, the Presidential Commission for the Study of Bioethical Issues said in its report on synthetic biology (Gutmann, et al., 2010) that:

> *Public deliberation is particularly valuable while the field is still young, as there is a unique opportunity to shape its development in ways most likely to promote the public good while assuring safety and security.*

The answers to questions raised by this field can be informed by both scientific and public perspectives. (The Hastings Center, 2008). Furthermore, work in synthetic biology is not limited to huge institutional government, academic, or industrial labs but includes a significant "do-it-yourself" component.

> *The emergence of synthetic biology, and off-shoots such as DIYbio, make the need for a rigorous, sustained and mature approach for assessing, and preparing for, the broad range of associated dangers and risks all the more pressing* (Bennet et al., 2009; Postrel, 2013; Haynes, 2013).

The tools for work in synthetic biology are sufficiently accessible that undergraduate students are able to participate. The International Genetically Engineered Machine competition (iGEM) is the premiere undergraduate synbio competition. Student teams are given a kit of biological parts at the beginning of the summer from the Registry of Standard Biological Parts. Working at their own schools over the summer, they build biological systems and operate them in living cells. In 2013, 204 teams participated in this competition worldwide (http://www.igem.org/)

The MSPES project will benefit from work done by the *Synthetic Biology Project* of the Woodrow Wilson International Center for Scholars, which aims to foster informed public and policy discourse concerning the advancement of synbio and provides independent, rigorous analysis that can inform critical decisions affecting the research, commercialization and use of synthetic biology. The *Synthetic Biology Project's* objective is to help ensure that, as synthetic biology moves forward, possible risks are minimized and benefits maximized (www.synbioproject.org/about/). Eleanore Pauwels, *Public Policy Scholar for the Synthetic Biology Project* will serve as an advisor for the MSPES project.

The MSPES project team will also include experts on synthetic biology from Synberc, the NSF funded Synthetic Biology Engineering Research Center, now in its eighth year, that is a collaboration of UC Berkeley, UC San Francisco, Stanford, Harvard, and MIT. Megan Palmer is a bioengineering research fellow at UC Berkeley and is the Deputy Director of Practices at Synberc. She manages a portfolio of projects to develop, promote, and advise on practices and policies for responsible biotechnology development, including the Leadership Excellence Accelerator Program, which aims to cultivate a generation of research leaders who can develop and promote practices and policies for responsible biotechnology development that is in the public interest. She has organized many forums on societal aspects of synthetic biology and ran programs examining the public role of science and technology.

Natalie Kuldell of MIT, who is a Synberc PI and Associate Education Director, will serve as a co-PI for the MPSES project. Dr. Kuldell is also President of the BioBuilder Educational Foundation, which already has experience implementing an effective educational approach that converts ongoing university-level research questions into modular teaching materials for formal education settings. BioBuilder has developed an impressive array of online animations, hands-on lab activities, and social networking frameworks around the basic concepts of synthetic biology (BioBuilder, 2013). These curricular materials

are presented through the open-access website, BioBuilder.org, and are supported by the BioBuilder Educational Foundation, a public charity formed with NSF support to disseminate the curriculum through teacher training workshops and presentations. Natalie Kuldell is also a core member of the Coalition on the Public Understanding of Science (COPUS), a group dedicated to teaching members of the public about complex scientific topics. To date, though, her activities have focused more heavily on the scientific concepts than on the inherent ethical issues. In addition, the curricular modules she has developed have been intended for students and teachers in formal education settings. Participation in MSPES will allow Dr. Kuldell to expand her work to PES topics in informal settings.

Although the MSPES project will focus on PES, a basic understanding of synbio will be an important "public understanding" component of the project, because little is known about the field by both public and ISE participants. But as the content of the project is developed, special emphasis will be placed both on questions that scientists would like to explore in discussion with the public, and that the public can contribute to in significant ways; and questions that the public would like to explore in discussion with scientists. A starting point for developing content will be consideration by the project team of topics like:

Risk Management: What processes should be put into place to ensure that health or environmental risks from synthetic biology are appropriately assessed and risks minimized?

Openness and Transparency: How transparent should the outcomes of synbio research be, including genetic information about novel organisms, given concerns about the potential for bioterrorism?

Community Coordination: How should the academic scientific community, the industry, and the DIY bio community work together?

Oversight and Regulation: How should we build a regulatory environment that reduces hurdles to innovation while protecting the public from unanticipated consequences?

Public Involvement: How should synthetic biology research be shared and communicated with the public, and what should the public role be in decision-making about synthetic biology policy?

Ethics and Equity: What process should be implemented for considering and responding to ethical concerns or objections to synbio research as they arise?

While the focus for the public programs will be synbio, and the ISE professionals will learn much about synthetic biology in this project, the fundamental content underlying the project is knowledge and skills related to public engagement with science, which will be described in Section B – Project Design.

Why this is innovative in the ISE field

The proposed MSPES project takes a next step for the field many of the priority areas described by ISE professionals for advancing PES in ISE identified in Table 2, with particular emphasis on priorities 3, 4, 5, and 9. The project is innovative because it will create resources for the field that do not currently exist to fill a need identified by prior work on PES in ISE. It will create a community of practice among eight institutions with the potential for leadership in PES and will tap expertise and the infrastructure created by the NISE Net project to disseminate PES materials to 200 sites in a very short period of time. Additionally, it will introduce to the ISE field broadly the topic of synthetic biology, which is mostly unfamiliar to ISE educators and the public. The primary focus of the innovation is to create resources, practices, and processes to integrate societal and ethical implications content as well as conversational techniques that are consistent with PES goals into the work of science museums in a way that supports scientist participation in multi-directional conversations with the public—a kind of programming for which there is a need but which is not yet prevalent in ISE. The MSPES project will also explore how to measure or evaluate PES, since current models and guidance for evaluating ISE have been derived primarily from the need to measure public understanding goals, not public engagement goals.

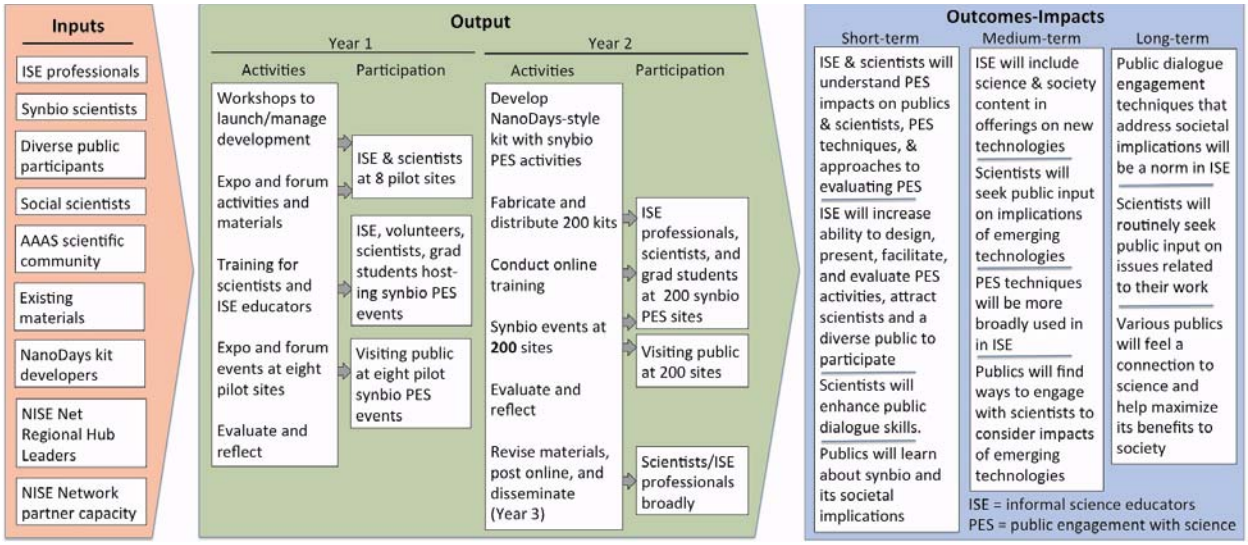
B. Project Design

Intended impacts on the informal STEM education field

There are three target audiences for this project: two direct audiences—ISE professionals at science museums, and scientists in the field of synthetic biology; and one indirect audience—the members of the public with whom the ISE professionals and scientists interact. The overall goal is to increase the capacity of the ISE professionals and the scientists to engage the public in multi-directional dialogue about the societal implications of new and emerging technologies and to advance the capacity of the ISE community to plan, implement, and evaluate PES activities with scientists, and to recognize the kinds of outcomes they achieve in comparison to activities that focus on public understanding of science. The

long-term strategy is that from this increased capacity a variety of benefits will accrue to the public, the scientific community, and society at large such as those related to democratic dialogue and decision-making, as well as greater understanding of emerging technologies and their societal impacts.

Figure 2. MSPES Logic Model



Project deliverables are designed to have strategic impact on the field by building the capacity of ISE professionals to be developers, facilitators, and evaluators of PES activities, with scientists as potential partners or even "clients" for whom the ISE professionals organize and implement the engagements. The intended **professional learning outcomes** for the project are:

Awareness, knowledge, or understanding

1. ISE professionals and scientists will have a deeper understanding of the potential impacts of PES on both scientists and the public and of how best to engage participants in PES.
2. ISE professionals and scientists will have an increased understanding of various techniques of public engagement and how they can be used in the context of socio-scientific issues relevant to civic life today, as well as ways to embed activities into the broader community, reach under-represented audiences, and sustain the impact of PES beyond a one-time event.
3. ISE professionals and scientists will have an increased understanding of both the challenges and potential solutions to evaluating PES activities, where the goals may be different from those driven by public understanding of science perspectives.
4. ISE professionals will have increased knowledge of synthetic biology and the societal implications it raises as well as strategies for engaging publics in learning about both.

Skills

5. ISE professionals will have an increased ability to design, present, facilitate, and evaluate PES activities, and to organize multi-site PES events that attract both the scientific community and a diverse public, including audiences underrepresented in participation in mutual learning.
6. Scientists will have increased ability in public communication and dialogue skills.

Other: Self-efficacy

7. ISE professionals and scientists will increase their feelings that they are able to conduct or participate in PES activities.

These professional learning outcomes are the short-term outcomes in the project's logic model and the ones on which summative evaluation of the project will be based. In order to achieve these impacts, the project includes a variety of deliverables, which will be created and delivered in the following order:

1. Three workshops in year 1 of the project for a core group of ISE professionals and synbio scientists to develop the content, techniques, activities, and materials for public engagement with synthetic biology.
2. Prototype versions of tools, guides, and materials for developing, implementing, and evaluating public engagement with science activities on the topic of synthetic biology.

3. Implementation of two types of PES events: one involving scheduled dialogue and deliberation by groups of participants (forum), and one involving more casual dialogue during exhibit hall table-top activities (expo); at eight (8) pilot sites across the U.S.
4. Evaluation and reflection on the effectiveness of the content, techniques, activities, materials, tools, and guides used at the pilot sites and recommendations for their improvement.
5. Redesign of the tools, guides, and materials for PES on synthetic biology and packaging into a kit similar to NISE Net NanoDays kits, and fabrication of 200 copies of the kit.
6. A process for recruiting and selecting partners and providing support for the use of the 200 kits through a regional hub structure similar to the structure used by the NISE Net.
7. Public engagement events focused on synthetic biology at 200 sites nationwide that include PES activities and collaborations between ISE professionals and scientists wherever possible.
8. Further revision of materials based on evaluation and feedback from 200 sites, and making all materials available on the web for free download and use by scientists, ISE professionals, and K-12 teachers beyond the scope of this project, including materials specific to synbio and materials applicable to PES more generally.
9. Framework for PES that can be transferred to other socio-scientific issues.

ISE organizations and synthetic biology research organizations have already been recruited for the Year 1 engagement activities that will take place at eight pilot sites. These include: 1) Science Museum of Minnesota and University of Minnesota, 2) Pacific Science Center and University of Washington, 3) Chabot Space and Science Center and the Synthetic Biology Education and Research Center, 4) the Museum of Science and M.I.T., 5) Museum of Life and Science and North Carolina State University, 6) Arizona Science Center and Arizona State University, 7) New York Hall of Science and the Genspace, and 8) Sciencenter and Cornell University. Letters from the informal educators and synbio scientists for the eight pilot sites included in the supplemental material illustrate the high caliber of these participants.

Workshops in Year 1 and Drafts of Engagement Materials
Representatives of these eight pilot sites will participate in three Year 1 workshops along with synbio experts, social scientists, diversity consultants, leaders in the work of the NISE Net, evaluators, and additional advisors and consultants as appropriate to the specific focus of each of the workshops.

- The first workshop will take place in Durham, NC, at the time of the Association of Science-Technology Centers conference in October 2014. It will launch the project, and provide project participants introductions to synthetic biology and public engagement with science, and establish the parameters, content map, strategies for serving diverse and under-represented audiences, work plans, and assignments for the development of activities for the Year 1 pilot engagement events. Following the first workshop, each host site will be responsible for developing one specific engagement activity to be included in the pilot events.
- The second workshop will take place in San Jose, CA, in conjunction with the AAAS Annual Meeting in February 2015. Building upon successful NISE Net program development practices, participants will bring prototypes of their engagement activities for feedback from ISE professionals, synbio scientists, and social science content advisors. A select group of activities will be presented to the public during AAAS's Family Science Days and members of the MSPES project team will get feedback from public visitors on their questions, interests, and concerns about synbio. Based on this 360-degree feedback, activity developers will modify the prototypes and complete their design.
- The third workshop will take place at the network-wide meeting of the NISE Net in April 2015 (likely in St. Paul). Activity developers will bring their completed activities, and demonstrate them for pilot site organizers. Additional orientation and training will be provided on implementing pilot events with particular focus on skills and techniques specific to PES, training host site presenters and volunteers recruited from their research partner organizations, recruiting participation from under-represented audiences, and evaluating and reporting on their pilot engagement events.

All of the materials developed by the eight host sites and other project advisors or consultants will be collected, edited as needed, and coordinated into a kit of materials for all eight sites to use during their pilot engagements. The materials will include modifications of materials existing prior to the launch of the MSPES project and newly developed materials. Existing materials to be modified as appropriate will be drawn from such sources as the educational outreach materials developed by Synberc, iGEM, and MIT's Biobuilder project, and from NISE Net's professional development tools such as the Forums

Manual, Team-Based Inquiry Guide, Universal Design Guide, and Designing for Bilingual Audiences Guide. New materials to be developed will include the specific instructions for conducting the MSPES pilot projects and the expo activities and forum materials needed to run and evaluate those events.

Pilot Engagement Events at Eight Sites in Year 1

The science museums and their research partners will recruit public participants for the engagement activities representing diverse audiences, along with expert participants from their local universities, DIYbio community, and iGEM teams in their regions. Two types of engagement events will be held.

Event 1**:** The *SynBio Expo* will showcase the field of synthetic biology and feature tabletop interactions, conversations, demonstrations, and presentations from synbio researchers, graduate students, undergraduates, and members of the DIYbio community. While these activities will be similar in some ways to NanoDays events, there will be a focus on interaction between scientists and the public; dialogue about the potential applications of synthetic biology; transparency about uncertainties, implications, risks, and possible effects on humans and the environment; and the practice of listening to public concerns about the research. NISE Net's *Nano and Society* guide and activities have begun the infusion of this kind of content and interactivity into traditional exhibit floor tabletop activities. The MSPES project will push this kind of interaction further toward PES.

Each pilot site will test the materials and activities provided by the project to form a common base for the expo events. But each is also expected to be enhanced locally by presentations and scientist chat opportunities developed by ISE and scientist partners at each site unique to content of interest and relevance in each specific community. Approximately 16-20 scientists and graduate students will be involved in the Expo events at each site, along with ISE staff facilitators and volunteers. MSPES advisors and consultants have identified key participants from the synbio community for each pilot site and will work with national organizations like iGEM to recruit additional local participants, including those from groups under-represented in science. The pilot site teams will conduct training for *SynBio Expo* participants at each site before the event to highlight best practices in science communication, drawn from NISE Net and Portal to the Public projects, and AAAS's experience in communication training for scientists, to prepare participants for their involvement. The *SynBio Expo* will be used to recruit members of the public and the scientist community to participate in event 2.

Event 2: The *SynBio Forum* will be a participatory, dialogue-based program. The *Forum* will bring together members of the public with scientists and other stakeholders who represent a diverse spectrum of community, policy, and ethical perspectives, to consider focused questions around the social and ethical implications of synthetic biology for society.

Questions for deliberation will be developed collaboratively by members of the MSPES Team, synbio advisors, and experts in dialogue, policy, and ethics. Emphasis will be placed on questions that scientists would like to explore the answers to in discussion with the public, and that the public can contribute to in significant ways; and questions that the public would like to explore with scientists. A starting point for developing content for the *SynBio Forum* will be consideration by the project team and synbio advisors of topics such as those described earlier in discussion of the STEM focus of this project. A Family Science Day activity at the AAAS Conference in San Jose, the site of the second planning workshop, will provide an opportunity for project team members to solicit interest from the public attending that event.

Approximately 8-10 scientists or graduate students from diverse backgrounds working in synbio will participate in each of the forum events, so that conversations can meet the PES goal of mutual learning for both public and scientist participants. *SynBio Forum* host sites will recruit participants, coordinate logistics, conduct the deliberative events, collect evaluation data, and disseminate and report on results. Pilot sites will recruit participants to achieve diverse discussion groups, working to include under-represented audiences through program marketing strategies and community partnering. MSPES project team members have experience in recruiting diverse participants through prior work on *World Wide Views on Global Warming* (2009) and *Biodiversity* (2012) global citizen deliberations, which required rigorous demographic and socio-economic criteria for participation. Program and publicity materials will be produced in English and Spanish, and partnerships between the local science centers and organizations such as community centers, churches, health centers, and schools will be employed.

Successful practices and models from MOS's forum work, the NISE Net, *World Wide Views on Biodiversity*, the *National Coalition for Dialogue and Deliberation*, *Public Agenda*, and the *National Citizens' Technology Forum* will inform the development of the details of the *SynBio Forum* and will be shared with pilot site teams. While most forum content and design will be consistent across all eight sites, some customization will allow local scientists, graduate students, and members of the public to connect local work with the

issues discussed. Social scientists and policy experts from ECAST will serve as advisors and consultants for the project to develop strategies for compiling the thoughts on the issues discussed by public and scientist participants in the forums at eights sites, supporting dissemination of these outcomes to professional audiences through ASTC, AAAS, and other professional communities represented in the project, as well as further discussion of the outcomes locally among scientists and the public.

Pilot sites will be provided with Team-Based Inquiry (TBI) tools for evaluating the effectiveness of the activities in both the expo and forum engagements and for identifying the impacts that the two types of engagements had on both public and scientist participants. One of the innovative activities this project will undertake is to create a framework for the impacts of PES activities. Existing impact frameworks have been developed primarily with the public understanding of science perspective, and are therefore not necessarily appropriate for PES activities. A PES framework and associated TBI tools will be prototyped along with the engagement activities at the eight pilot sites in year 1 of the project. ISE professionals from the eight pilot sites will meet with project advisors at the ASTC conference in October 2015 to share their experiences with using the tools and materials for running expo and forum engagement activities, and to reflect on the impacts of those activities on the participants. The purpose of this activity is to build the capacity of those ISE professionals for planning, implementing, and evaluating public engagement with science in informal science education environments.

C. Dissemination Plan

Year 2 of the MSPES project will go beyond simply reporting on project outcomes at conferences and in publications and will constitute a significant second phase of work in the Project Design, only the first year of which was described in the prior section. Work in year 2 will test the potential of using the infrastructure and increased capacity within the ISE field resulting from the 10-year, NSF-funded Nanoscale Informal Science Education Network project.

PES Kits and Events at 200 Sites in Year 2

The MSPES project will tap into the infrastructure developed by the NISE Net project to disseminate PES activities and practices focused on the topic of synthetic biology to 200 sites across the U.S. in year 2 of the project. The materials developed in year 1 will be revised based upon formative evaluation of their effectiveness conducted using Team-Based Inquiry in the pilot engagement activities, designed, and packaged to be part of a *SynBio Kit*, that will build upon the successful practices of the NISE Net kit development process and personnel from the Science Museum of Minnesota and the Sciencenter in Ithaca who have led that work. Several of the MSPES pilot sites have been involved in NISE Net program, materials, and kit development, and so the focus on designing materials for broad dissemination will be part of the work starting from the very beginning of the project and will be finalized based upon the outcomes of the Year 1 pilot engagement activities.

The MSPES project will use an application process for disseminating the kits at no cost, but applicants must agree to use the kit during the summer of 2016 to support *Summer of SynBio* public engagement events and activities at their institutions, to partner with researchers in synthetic biology or a related field (if available in their community), to reach out to diverse and under-represented audiences with the kit materials, and to complete reports on their activities at the end of the summer. All of this is consistent with the kinds of requirements NISE Net has placed on recipients of NanoDays kits. Furthermore, in a 2013 NISE Net Annual Partner Survey respondents indicated a strong interest in exploring new emerging technologies beyond nanotechnology for their programs in the future, and rated both online and physical kits as the kinds of resources they would value most beyond the ten years of the NISE Net project. To provide local scientist support, project partners at AAAS, Synberc, and ECAST will help to recruit diverse scientists from around the country to participate in *Summer of SynBio* events.

Seven regional hubs will provide support and encouragement for ISE partner involvement in *Summer of SynBio* activities and events. They will provide potential kit recipients with periodic updates on the project, information on how to apply for a kit, reminders about deadlines and requirements, and help with questions that come up and with identifying potential partners from the synthetic biology research community. Regional hub leaders will participate in conference calls with MSPES project leaders to become knowledgeable and current on MSPES activities.

While this dissemination will tap into work developed by the NISE Net over ten years, it will include several innovative components. (1) It will introduce a new topic of current scientific research and development to hundreds of ISE organizations in a short period of time. Nanotechnology was introduced to the field over several years; synthetic biology will be introduced over several months. Partners that

have had various levels of responsibility within the NISE Net project indicate that they are interested and ready to tackle a new topic. The MSPES project will thus test the readiness of the field to take on a new unfamiliar topic and to incorporate it quickly into public engagement activities. (2) The MSPES project will focus on PES, through activities that are derived from a PES perspective, like forum programs, and also activities derived from a public understanding perspective, but with topic and participation characteristics of PES mixed in, such as exhibit hall table-top activities that stimulate a discussion between science graduate students and members of the lay public about the potential applications of synthetic biology that each values the most and why. (3) Despite the clear value of face-to-face meetings and trainings for building a participant community and its capacity to take on new work training and support for the 200 sites participating in the Year 2 activities will be provided by written guides in the kit of materials, training videos, online webinars, and individual encouragement and support from the regional hub leaders. Project leaders, synbio scientists, regional hub leaders, and developers of engagement activities, as appropriate, will lead online training sessions and webinars to build the capacity of the field to make full use of the materials distributed in the kit. If effective, this will yield a lower-cost model and structure for future broad dissemination of materials and activities on other topics.

Dissemination beyond the 200 sites in Year 3

The reports that kit recipient sites complete at the end of the summer of 2016, additional TBI studies, and summative evaluation will inform the project team concerning additional modifications to the activities and support materials developed by the project. Revised materials will be posted on the project website so that they are available to anyone who wants to use them. Links to the materials will be established on sites at which various communities potentially interested in public engagement with synthetic biology might look to find resources. Synberc and AAAS project partners will communicate the existence of these resources, information about, and findings of the MSPES project within the synthetic biology and general science communities. The Museum of Science, the Science Museum of Minnesota, and other ISE project partners will communicate the existence of the resources and the findings of the MSPES project within the science museum community generally and through the ASTC PES and Evaluation Communities of Practice (CoPs), and the Visitor Studies Association (VSA). Members of the ECAST network will communicate the findings of the project within the social science, political science, and policy communities that may be interested in potential vehicles within society to support anticipatory governance, participatory technology assessment, and other broader potential societal benefits of PES.

Broader Impacts

In addition to materials posted only to support the specific types of PES activities developed in this project to engage the public in learning about synthetic biology, the project team will also launch the initial version of an online Guide to Developing, Implementing, and Evaluating PES Activities. The Guide will draw upon prior work and published materials relevant to the topic (from NSF-funded

Table 3. Draft Outline of Potential Content for the MSPES Guide

1. Discussion of the definition of PES drawn from the CAISE report (multi-directional transfer of knowledge and mutual learning) with added material on participatory democracy and other purposes of PES as identified in the ISE evidence wiki (http://iseevidencewiki.org);
2. Discussion of how understanding why you want to do a public engagement activity, who the stakeholders are, and what your hoped for outcomes are, helps you decide on the structure and design of the engagement activity;
3. Concrete examples of past engagements with links to websites where material can be downloaded so the reader can replicate and experience an already designed engagement, drawn both from the *Dimensions of PES* project discussed earlier and more recent PES activities;
4. A step-by-step guide for planning and designing an engagement activity, drawing upon the existing literature and illustrating how they applied to the development process used in the engagement activities of the MSPES project: 1) identifying the purpose of the engagement and stake-holders who care about the outcomes, 2) working with stakeholders to clarify goals and intended outcomes, 3) examining options in the design of the engagement, 4) developing program components and supporting materials, 5) recruiting expert and public participants including non-traditional underrepresented audiences, 6) conducting a PES activity, and 7) evaluating a PES activity
5. Discussion of disseminating PES engagement outcomes. For the MSPES project, this includes both the recommendations that forum participants make about the topic of the forum (e.g. the balance between intellectual freedom and safety regulation for do-it-yourself synthetic biology), and dissemination of the PES program model (making it possible for others to replicate the engagement activity or use the format for another topic.)
6. Tips on designing PES activities so that scientists, the public, and ISE institutions find them beneficial.
7. A database function that will allow institutions hosting the MSPES engagement activities to upload evaluation data and the recommendations and results of participant deliberations.

work on PES as well as materials developed by such organizations as the *National Coalition for Dialogue*

and Deliberation, *America Speaks*, and *Public Agenda*), as well as the work of the MSPES project itself. The MSPES online guide will be updatable as new projects are developed in the future, new materials developed, and new knowledge generated. The Guide will be developed as the project moves forward but initial thoughts on its content are shown in Table 3 above.

The MSPES project is a step toward broader long-term impacts of PES. If through this project we can help informal science educators learn how to include content related to societal implications of current and emerging scientific research into their program offerings, and help scientists see how they can use public engagement on the societal implications of current and emerging science and engineering to benefit their own work, then we can imagine a future in which many of the needs cited earlier in this proposal are met. Public dialogue and engagement techniques that address societal implications of science and technology will be a norm in informal science education. Scientists will pro-actively and routinely seek public input on societal issues of interest to them related to their work. And the public will discover ways in which they can engage with scientists to consider impacts and policies related to emerging technologies, feel a connection to the enterprises of scientific research and technological development, and contribute to efforts to maximize their benefits to society.

D. Evaluation and External Review

Front-end, formative, and summative evaluation will be conducted in part by internal evaluators on the project team and in part by external evaluators. For the purposes of evaluation, the professional audiences are identified as being members of three different tiers: Tier 1 professionals are part of the core project team, Tier 2 includes ISE professionals and scientists directly implementing PES activities at the eight pilot sites, and Tier 3 professionals are members of the ISE and scientist communities involved in *Summer of SynBio* activities at 200 sites. The three Tiers represent different levels of involvement in the project by the various ISE professionals and scientists involved.

Front-end evaluation for the MSPES project was carried out in the NSF-funded *Dimensions of PES* project described earlier in this proposal. In that work we got a snapshot of the state of the art with respect to PES in the ISE community and engaged key members of the community in describing what supports they needed to advance PES in their own work. Additional front-end and formative evaluation will be conducted by members of the Tier 1 evaluation work group, which will include evaluators from the Museum of Science, and the Science Museum of Minnesota; who in the course of exploring evaluation methods for the pilot engagement projects, will provide the project team with data that will be used to guide decisions about the pilot engagement activities, including the goals for scientist and public participants, the formats and content for the events, and materials to support pilot sites in conducting evaluations of the engagement outcome.

Tier 1 team member evaluators will conduct two activities to aid Tier 1 and 2 in articulating public and scientist impacts for the pilot public engagement projects: 1) review existing PES activities and evaluation metrics; and 2) conduct interviews with scientists who have already participated in PES activities. The first front-end activity will be to gather and summarize information about the range of impacts articulated for other PES activities, which focuses primarily on outcomes for public participants.

The second front-end activity that Tier 1 evaluators will conduct is a series of interviews with approximately 12 scientists who have already participated in one of two different kinds of engagement activities relevant to this grant: meet-the-scientist expo events, and dialogue and discussion forums. Information from these interviews will help the project team understand why these scientists decided to participate in the events and what they found to be the benefits of their participation. Resulting insights will be used to inform project participants from the ISE community in thinking about how to best attract and support scientists participating in PES activities, as well as inform discussions about how to appropriately articulate impacts for scientist participants.

Formative evaluation. The main work of the Tier 1 evaluators will be to explore methods that can be used to understand the impact of PES activities on scientist and public participants. This work will not only be helpful to those hoping to better understand how to evaluate PES activities but also to practitioners hoping to understand potential impacts of the events they develop in the future. As the intent of MSPES is to develop and provide materials that enable ISE institutions to independently conduct and evaluate PES events, our approach is to support ISE professionals in a practical participatory evaluation (Cousins & Earl, 1995). Tier 1 evaluators will train ISE professionals to collect evaluation data at their individual PES events. The evaluators will then analyze the data and present preliminary results to Tier 1 and 2 group members at data debriefs. These debriefs will be held with those practitioners who

implemented the pilot engagements to understand their interpretations of the evaluation findings. These sessions will allow Tier 1 and 2 participants a chance to interpret evaluation findings and further understand the contexts surrounding the different pilot engagement events. Debrief information along with the evaluation data from the Year 1 events will be used to inform decision-making about the Year 2 pilot engagement. Additionally, as a part of the debriefs, Tier 1 evaluators will ask Tier 1 and Tier 2 ISE professionals to discuss the usefulness of the evaluation data collected to informing their future work, and their feelings about their ability to collect data using the evaluation instruments. This information will be used to guide changes or refinements to questions, instruments, and methods.

Summative evaluation will be conducted by *Rockman et al (REA)*, Saul Rockman, President. As independent researchers, REA often serves as external evaluators for grant-funded projects supported by foundations, state and federal agencies, and industry. REA has a strong reputation for providing evaluation services in ISE focusing on professional audiences. The purpose of the summative evaluation is to determine the extent to which PES project initiatives deepen ISE professionals' knowledge about developing and conducting PES activities and affect their subsequent event planning and implementation, as well as scientists' understanding of how to engage publics through PES. Increases in understanding of potential benefits of PES, strategies for engaging scientists and publics in PES, challenges and potential solutions to evaluating PES, how to use PES to address socio-scientific issues, embedding PES activities in communities, reaching underserved audiences, as well as refined skills in and confidence around designing, communicating, facilitating, evaluating, and sustaining the impact of PES activities will be examined for three target audiences: Tier 1 (i.e. the core project team and working group of three institutions), Tier 2 (i.e. ISE professionals and scientists directly implementing PES activities at the eight pilot sites), and Tier 3 (i.e., ISE and scientist community involved in Year 2 SynBio activities at 200 sites.)

To explore the impact of participation in PES initiatives on the Tier 1 audience, REA will interview at least ten project team members at the beginning of Year 1 and again at the end of Years 1-3 to track how Tier 1 participants' thinking and approaches have changed as a result of coordinating efforts and evaluating PES initiatives. REA will sample both scientists and ISE professionals on the project team to ensure representation from both groups. In Year 3, REA will do a textual analysis comparing themes identified in past Tier 1 interview responses to information presented in the written Guide to Developing, Implementing, and Evaluating PES Activities to determine the extent to which lessons learned by the project team were reflected in the final document.

To examine the impact of PES participation on Tier 2 audiences, REA will collect pre, post, and follow-up surveys via email from representatives at eight sites that take part in the synthetic biology PES events. Surveys will use questions modified from the *Dimensions of Public Engagement with Science* Workshop Survey, an instrument created for the original Pathways project. REA will also conduct more in-depth interviews with a subset of Tier 2 participants from each initiative to better understand the impacts of the project on ISE professionals and scientists' ability to plan, organize and carry out successful PES activities. Here, REA will investigate the preparation and training of Tier 2 ISE professionals and scientists who take part in Expo events and compare the impacts of those activities to the impacts on Tier 2 participants who plan and conduct Forum events.

To explore the impact of MSPES on Tier 3 audiences, REA will develop a pre-post survey for ISE professionals and scientists who attend PES online trainings and implement at least one of the kits. Survey questions will address what Tier 3 audiences learned about how to engage scientists and publics around PES content from the trainings and their own experiences implementing the kits at the institutions, as well as the perceived benefits and challenges of developing and implementing PES activities. REA will also conduct online focus groups after online training sessions to find out whether outside institutions were able to utilize the online materials and the extent to which they felt prepared to implement one of the kits at their institution as a result. A subset of Tier 3 participants will be interviewed after kit implementation to determine what they learned about conducting PES activities for public audiences at their institution. The results of these interviews will be compared to data collected from Tier 2 audiences to determine whether there are differences in the level of impact on ISE professionals and scientists' understanding of PES based on type of training and method of implementation (A detailed evaluation plan can be found in supplementary documents.)

E. Project Management

The MSPES project includes a leadership team drawn from the Museum of Science (MOS) in Boston, which has a long history of research and evaluation of PES, and in developing and conducting over 50

dialogue programs on a wide variety of topics and in various inventive formats since 2003; the American Association for the Advancement of Science, the world's largest general scientific society serving 10 million individuals, and whose CEO is a strong proponent of public engagement with science; the NSF-funded Synthetic Biology Engineering Research Center (Synberc), the Biobuilder Foundation, and MIT, which bring expertise in the field of synthetic biology and connections to a wide range of synbio scientists; and the Science Museum of Minnesota and the Sciencenter in Ithaca, which bring experience in evaluation and in developing, fabricating, and distributing NISE Net's NanoDays kits and disseminating engaging activities to hundreds of sites across every state in the nation. The MSPES project will also draw upon expertise from the ECAST Network (Expert and Citizen Assessment of Science and Technology) which provides experience in coordinating engagement activities across multiple sites and disseminating outcomes; CSPO (Consortium for Science, Policy, and Outcomes at Arizona State University), which provides social and political science expertise and experience in working with ISE organizations to create engaging educational activities; the Woodrow Wilson International Center for Scholars, which has done groundwork on societal implications of synthetic biology; experts from the Exploratorium and the Association of Science-Technology Centers in reaching and serving diverse and under-represented audience; and other experts as needed in synthetic biology, social and political sciences, and evaluation. While this project includes many partners and a complex set of activities, the leadership team draws upon its experience in leading the NISE Net to coordinate the work across all phases of this project.

The **leadership team** will provide overall coordination of MSPES activities to maximize achievement of the project's professional audience learning objectives. It has oversight of all project activities. It will meet in person in its entirety four times during the project and in monthly conference calls.

From Museum of Science: •Larry Bell, Sr. V.P. for Strategic Initiatives, has 42 years experience in informal science education and 11 years experience with dialogue-based PES. He will serve as PI and overall project lead. •David Sittenfeld, Program Manager for Forums, develops and presents activities that engage various publics in conversations around emerging topics in science and technology. He brings experience working on the NISE Net Forum team, two *World-Wide Views* projects, and a variety of other forum programs. He will lead the effort to develop engagement activities for the PES pilots. •Elizabeth Kunz Kollmann, Sr. Research and Evaluation Associate, co-PI of the NSF-funded *Dimensions of Public Engagement with Science*, and leader of the NISE Net evaluation team. She brings experience conducting over 30 evaluations and PES activities and will lead development of PES evaluation tools. •Christine Reich, Director, Research and Evaluation, and leader of the NISE Net evaluation team, brings experience in evaluating PES activities and multiple outcomes of a large network.

From AAAS: •Tiffany Lohwater, Director of Meetings and Public Engagement, has 13 years of experience in public and scientific events, science writing, and public engagement with science, and will provide strategic leadership to the MSPES project and oversight to AAAS's efforts •Jeanne Braha, Public Engagement Manager, develop and implement scientist training and develop strategies for the inclusion of scientists in MSPES, facilitate the programmatic aspects of the digital community for the MSPES project, contribute to the framework for PES and disseminate it beyond the ISE community.

From MIT: •Natalie Kuldell, PhD, Instructor in Biological Engineering at MIT, Director of the BioBuilder website, Associate Education Director, and COPUS regional hub coordinator, brings expertise on synthetic biology, curriculum, and public outreach

From SMM: •Catherine McCarthy, PhD, Project Leader for NISE Network at SMM, will serve as a member of the Leadership team and will manage SMM's role in the project. She will also serve on the SynBio kit development team and provide coordination of the regional hub leader group. •Sarah Cohn will act as full member of the evaluation team. Her main role will be to help the team develop and present professional development around the Team-Based Inquiry (TBI) evaluation methods that are used as a part of this project based on her experience leading the TBI team for the NISE Network.

From Sciencenter: •Ali Jackson, Director of National Collaborative Projects for the Sciencenter in Ithaca, will provide overall leadership and coordination for the SynBio kit development team, including program and activity development, prototyping and visitor testing.

Consultants. The leadership team will be augmented by others with specific relevant expertise as needed.

Megan J. Palmer, PhD, Deputy Director of Practices, Synthetic Biology Engineering Research Center, UC-Berkeley will assist in development of the synbio engagement materials, provide content expertise, recruit synbio scientist participants for PES activities, and disseminate outcomes within the synbio field.

Jameson Wetmore, PhD, Associate Professor, Consortium for Science, Policy & Outcomes and School for Human Evolution and Social Change, Arizona State University, brings social science content expertise

and experience working with ISE staff in developing educational activities on science and society.

Ira Bennett, PhD, Assistant Research Professor, Consortium for Science, Policy & Outcomes and Center for Nanotechnology in Society, Arizona State University, brings social science content expertise and experience building grad student and ISE educator skill sets related to science and society.

Laura Huerta-Migus, Director, Professional Development and Inclusion, Association of Science-Technology Centers, will advise the project leadership and participants at every step of the process what we can do to make the ultimate benefits as accessible as they can be to a broad and diverse audience.

Veronica Garcia-Luis, Research Associate, Exploratorium, will advise leadership and participants throughout the project on the strategies and resources available to reach and serve broad and diverse audiences including those under-represented in science and engineering.

Angelina Ong, Principal, Spotlight Impact, brings experience with audience evaluation including Pacific Science Center's *Portal to the Public* project to help with development of PES evaluation tools and training.

Mahmud Farooque, PhD, Associate Director, Consortium for Science, Policy & Outcomes DC Office, ASU, and co-coordinator of U.S. participation in World-Wide Views for Biodiversity, will help with collection and dissemination of outcomes from public and scientist engagement activities.

Gretchen Gano, PhD Candidate in Human and Social Dimensions of Science and Technology at ASU, brings experience with ECAST work on *World-Wide Views on Biodiversity* and will help develop engagement activities and methods for collecting and sharing views of engagement participants.

Advisors. The following individuals bring specific expertise to augment that of the working groups:

Darlene Cavalier, Founder, *Science Cheerleader* and *Scistarter.com*, and co-founder of ECAST, will provide guidance on participant recruitment and dissemination strategies for public engagement outcomes.

Leslie Goodyear, PhD, Principal Research Scientist, Education Development Center brings experience in evaluating informal and out-of-school time educational programs with a focus on STEM education.

David Guston, PhD, Professor of Political Science and co-director of the Consortium for Science, Policy and Outcomes at ASU brings STS expertise and perspectives on anticipatory governance.

Eleanore Pauwels, Public Policy Scholar, Science and Technology Innovation Program, Synthetic Biology Project, Woodrow Wilson International Center for Scholars brings expertise on synthetic biology and will assist in the development of the synthetic biology engagement and materials to support it.

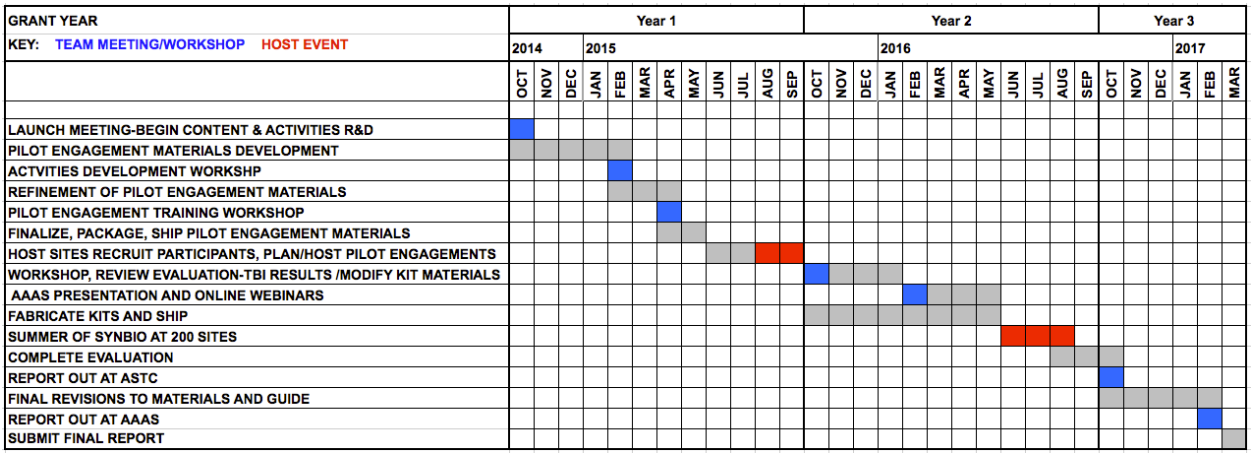
Dietram Scheufele, PhD, Professor, Life Sciences Communication, University of Wisconsin, Madison brings expertise on public opinion on emerging technologies and political effects of mass communication.

Meena Selvakumar, PhD, Acting V.P. for Strategic Programs, Pacific Science Center, brings expertise in forum programming and training scientists to engage with publics in the Portal to the Public project.

Rick Worthington, PhD, Professor of Politics, Chair of Program on Public Policy Analysis, Pomona College, brings expertise on environmental action, globalization, and science policy.

Eight ISE and synbio research organizations identified earlier in the proposal will partner as pilot sites and have provided letters of commitment (attached). The seven NISE Net regional hub leaders have committed to helping with dissemination to 200 sites and have submitted letters (attached). Each region has committed research partners including Rice University (Houston) and others previously mentioned.

Figure 3. Work Plan Timeline



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