Public Engagement with Neuroscience and Society

Conference Report and Vision for a National Informal Neuroscience Education Initiative

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This report was based on work supported by The Kavli Foundation. Any opinions, findings, and conclusions or recommendations expressed in this report are those of the authors and do not necessarily reflect the views of the Foundation.

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September, 2018

TABLE OF CONTENTS

BACKGROUND

The human brain and emerging neurotechnologies represent a frontier of 21st century scientific discovery with far-reaching implications. Understanding the brain was identified by the National Research Council (2010) as one of the five "most urgent, most important, and most achievable" grand challenges at the intersection of the physical and life sciences. Through large-scale collaborative, interdisciplinary efforts, like the Brain Research through Advancing Innovative Neurotechnologies (BRAIN) Initiative in the United States and others around the world, the next decade will bring amazing advances in understanding brain function, creating new tools for imaging and analysis, diagnosing and treating brain disorders, and developing novel theoretical frameworks with broad applications.

Given that modern neuroscience research is rapidly changing the landscape of human scientific understanding, with immense growth in both public- and private-sector investment, it is essential to engage the public in shaping the future of neuroscience. As described in a report from the NIH Blueprint for Neuroscience Research (2008), the interdisciplinary field of neuroscience has the potential to broaden science education in the United States—in content, audience, and capacity—through a truly human-centered approach. In this landscape, informal STEM education is an important foundation for public neuroscience engagement, encompassing basic scientific phenomena, new discoveries, and societal impacts.

In January 2018 the National Informal STEM Education (NISE) Network, in partnership with The Kavli Foundation, held a two-day strategic planning conference to conceptualize a national informal science education initiative around brain science (Box 1). Working with the Society for Neuroscience and other key stakeholders, the conference brought together a diverse group of museum professionals, scientists, social scientists, and other experts in informal science and neuroscience education to assess emerging issues in the field and identify needs and opportunities for outreach and engagement. The full conference agenda and a list of participants are included in Appendix A.

This white paper provides an overview of key themes that emerged from the conference and outlines a collective vision to grow public engagement efforts in concert with the rapid advancement of neuroscience research. This vision is centered on empowering multiple and diverse audiences to experience, talk about, reflect on their personal and community connections with, and contribute to broad understanding of and thoughtful dialogue about STEM research and its applications.

Box 1: Conference Goals
Participants representing a breadth of expertise relevant to informal neuroscience education will **share emerging science, educational assets, and effective strategies** for public engagement.
Guided by these perspectives, participants will **establish a framework of core neuroscience concepts and their societal impacts** that can be infused into informal education and outreach efforts.
Participants will **identify the need and capacity for professional development** in neuroscience and science communication for scientists, informal educators, and other stakeholders.
Through collaborative discussion and networking opportunities, participants from diverse organizations will **form relationships and explore potential collaborations** for informal neuroscience outreach, including a plan for mobilizing the extensive NISE Network for public informal neuroscience education.

Organizing Partners

National Informal STEM Education Network

The National Informal STEM Education (NISE) Network is a community of informal educators and scientists dedicated to supporting learning about science, technology, engineering, and math (STEM) across the United States. The mission of the Network is to build the capacity of informal science education institutions and research organizations to work together to raise public awareness, understanding, and engagement with current science, technology, engineering, and math (STEM). Past and current projects have focused on a variety of STEM topics including nanotechnology, Earth and space science, synthetic biology, chemistry, sustainability, and responsible innovation. NISE Network projects develop educational products and implement them with multiple and diverse public audiences, provide professional development for practitioners, and create opportunities for collaboration and networking (Fig. 1).

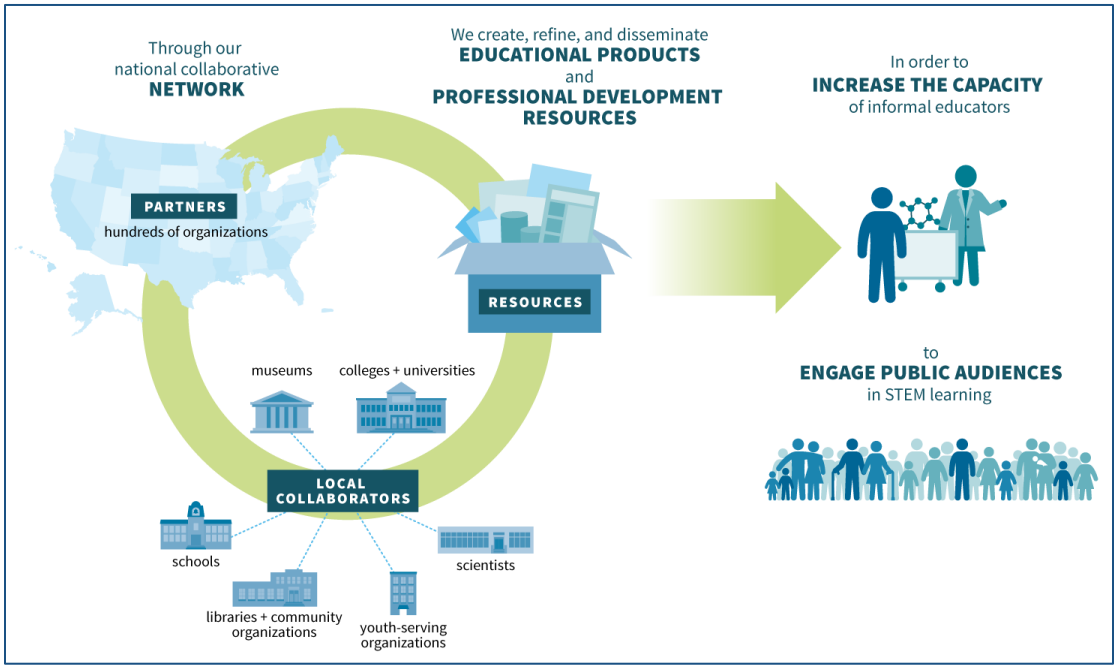

Figure 1. Impacts and structure of the NISE Network. This logic model illustrates the framework through which the Network leverages the resources of both informal STEM education organizations and research institutions to impact both public and professional audiences.

The NISE Network achieves its reach and impact through the participation of over 600 partner organizations—primarily science centers, museums, and college/university outreach programs located in the United States—in Network activities each year. The core organizations of the Network create resources and coordinate activities on a national and regional level through an established hub structure, while Network partners coordinate and implement project activities locally. Through the diversity of our partner organizations and their local collaborations, the Network has broad geographic

and demographic reach across the country. Together, partner organizations engage approximately 11 million people each year in high-quality STEM learning through the direct use of Network products (Swarovski et al. 2015). The NISE Network also advances the professional field of informal learning by incorporating current science into museum exhibits and programs, improving the practices and skills of educators and scientists, and creating lasting, valuable relationships among individuals and organizations.

An important and innovative focus of NISE Network projects has been to create programs designed to empower museum educators, scientists, and visitors to explore how new technologies may affect people and the societies they live in and create. These projects are different from many other outreach programs because they encourage public audiences not just to learn from experts about science and technology, but to participate as equals in the conversation. To achieve this, the Network has developed strategies that help people think through what their values are, better understand how other people think about values, recognize the expertise they have, and increase their confidence to contribute to the broader discussion about these technologies (Herring 2007; Wetmore et al. 2013).

As the NISE Network has explored diverse topics in STEM, input from partner organizations has influenced the Network's efforts in expanding its directions. Neuroscience has frequently emerged as a topic of particular interest. In a recent network-wide survey, 93% of respondents indicated that a focus on the topic "brain and neuroscience" would be valuable to them (Rosino et al. 2014). Of the survey respondents, 66% were from museums or science centers, while 33% were from universities, industry, or government, suggesting that the topic has broad appeal across different types of institutions.

The Kavli Foundation

The Kavli Foundation is dedicated to advancing science for the benefit of humanity, promoting public understanding of scientific research, and supporting scientists and their work. The Foundation's mission is implemented through an international program of research institutes, professorships, and symposia in the fields of astrophysics, nanoscience, neuroscience, and theoretical physics as well as prizes in the fields of astrophysics, nanoscience, and neuroscience.

The Kavli Foundation supports an international network of seven Kavli Neuroscience Institutes that carry out fundamental research in neuroscience. The Foundation was instrumental to the development of the BRAIN Initiative and plays a key role in coordinating various international neuroscience projects. As part of the BRAIN Initiative Alliance, the Foundation aims to inform and engage the public and the scientific community about emerging scientific successes and opportunities for further discovery. In alignment with these goals, The Kavli Foundation provided funding for the January 2018 conference to facilitate an open dialogue and exchange of ideas about public engagement with neuroscience.

Location and Additional Participants

The Franklin Institute in Philadelphia was chosen as the conference site to allow participants to experience and be inspired by the creative approaches to neuroscience outreach represented in the museum's *Your Brain* exhibition, which focuses on the neuroscience and psychology of the human

brain. The American Alliance of Museums recognized *Your Brain* with an Excellence in Exhibitions Award in 2015, citing the exhibition's "ability to successfully take a very dense subject matter and make it relatable to the visitor" (Hoffstadt 2015). The exhibition serves as an anchor for the Institute's broad range of neuroscience programming, including K-12 curriculum development, public programs, educator and corporate professional development, and research partnerships. The Institute is also an active member of the NISE Network's extended leadership group.

Conference attendees (listed in Appendix A) were invited to represent a spectrum of expertise ranging from informal science education to primary neuroscience research. Informal science educators included staff from various science and children's museums, leaders in professional development, experts in informal learning, and representatives from relevant national networks and professional associations including the Afterschool Alliance, National Girls Collaborative Project, and the Association of Science-Technology Centers (ASTC). To provide scientific expertise, participants included individual scientists and key organizations involved in neuroscience research and outreach, including the Society for Neuroscience (SfN) and The Dana Foundation, which jointly promote Brain Awareness Week, an annual global outreach campaign. Participants from Arizona State University's School for the Future of Innovation in Society and the University of Pennsylvania's Center for Neuroscience & Society were invited to guide discussions about the societal impacts of emerging neuroscience.

SYNTHESIS OF CONFERENCE PRESENTATIONS

To provide context for participants and lay a common foundation for discussions, the conference opened with a series of presentations given by various experts in neuroscience and informal science education. The following sections briefly summarize those presentations.

Current Research Priorities and Societal Implications

Frances Jensen from the University of Pennsylvania, chair of SfN's Public Education and Communication Committee, summarized the state of current neuroscience with an overview of how a coordinated interdisciplinary effort, along with significant investment in neuroscience, has guided the development of an ambitious research agenda in the past few decades. From the molecular level to plasticity and development over the lifespan, innovative new tools and emerging discoveries are transforming our understanding of the brain.

To understand how brain circuits are structured and change over time, researchers are aiming to create a complete library of different cell types based on gene expression. Techniques such as the "Brainbow" genetic system help to decipher the physical connections between these cells, and an effort to create a complete wiring diagram of the retina (including the crowd-sourced game Eyewire) is currently in progress. Optogenetics is another powerful new tool to identify the macro-level effects of microcircuits in the brain, enabling researchers to precisely manipulate neurons and observe the resulting changes in neural activity linked to specific behaviors.

Advancements in imaging (Fig. 2) have had an unprecedented impact on both human and animal neuroscience. At a structural level, diffusion magnetic resonance imaging (MRI) reveals how myelinated white matter tracts connect different regions of the brain, providing insight into brain organization and maturation. Functionally, advanced imaging techniques allow researchers to probe and map both primary and higher order functions, including studies on the greater risk of depression in adolescents and the neural circuits that are involved in decision making. These new techniques enable not just new avenues of inquiry in basic science but also new clinical applications, such as noninvasive stimulation of neural circuits to treat neuropsychiatric disorders.

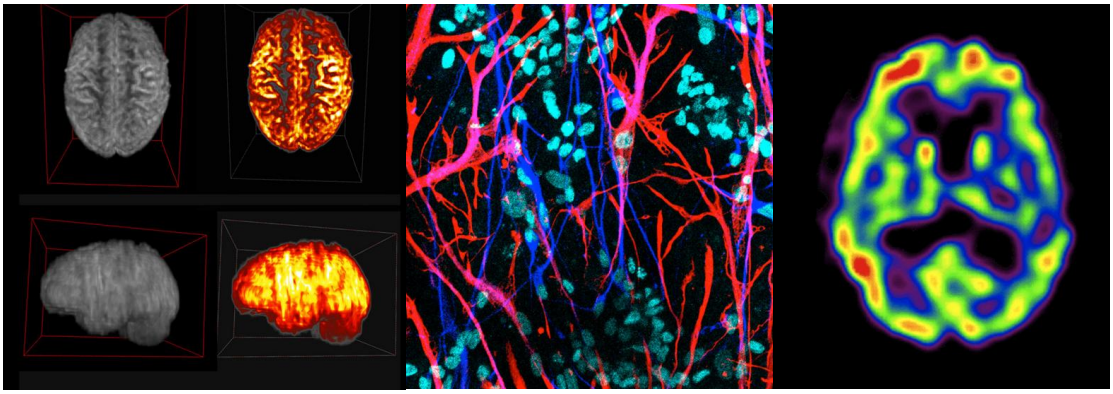

Figure 2. Sophisticated imaging techniques reveal new insights into brain structure and function. *Left*: Blood flow superimposed on MRI, an imaging technique used to study the effects of diseases such as stroke, epilepsy, and dementia. J. Detre & M. Fernandez-Seara, University of Pennsylvania and University of Navarra. *Center*: Fluorescent staining and microscopy show neurons created from human skin cells, a system developed to increase the supply of neurons for use in research and drug discovery. F. de Vrij, N. Gunhanlar, Laboratory of S. Kushner, Erasmus Medical Center. *Right*: PET scan showing blood flow in the brain during prayer, revealing increased activity (red) in attention and language regions. A. Newberg, Thomas Jefferson University Hospital.

Jensen emphasized that no other organ undergoes as much dramatic change in function over the lifespan as the brain, and examining how the brain changes in both health and disease is a critical meta-issue in neuroscience. Brain connectivity progresses from the back of the brain to the frontal lobe over a time period of more than 20 years from childhood to early adulthood, with implications for physical and cognitive development. Current research is investigating patterns of cell birth, migration, myelination, synaptic production, and pruning to determine the effects of disorders ranging from fetal exposure and prematurity at birth to neurodegeneration in old age.

The integration of big data, encompassing fields such as engineering, genomics, and computer science, is critical to many areas of neuroscience, but may have the greatest impact on breaking down silos in the study of brain diseases. Using interdisciplinary tools and investigative approaches has revealed common cellular mechanisms in autoimmune diseases, stroke, epilepsy, and other diseases.

The revolution in brain science is wide-reaching, from gene editing to neurodevelopmental disorders to artificial intelligence. Jensen framed the implications for many aspects of our lives that result as research pushes forward our understanding of the brain. Neuropsychiatric disorders are currently the leading disease burden in the United States, and new applications of emerging neuroscience to

diagnostics and therapeutics are transforming medicine. Critically, insights into learning, memory, and social behavior are increasing self-efficacy in personal choices that influence lifespan and aging. The behavioral psychology of decision making is gaining traction in the business world, while in the legal realm, there are moral and ethical issues at the intersection of criminal behavior and mental illness. New techniques and big data are raising unprecedented questions about education, marketing, and even arts and aesthetics.

As scientific techniques allow us to dive deeper into brain circuits and genetics, there are resulting complexities emerging at the individual and societal level.

Importance of public engagement

Jensen also discussed that for the scientific community, actively engaging with the public around core concepts and current research in neuroscience could have many potential benefits. Communicating the tangible everyday relevance of neuroscience creates a fact-based foundation for lifelong learning as science advances. An informed public can support advocacy for science at the governmental level at a time when funding levels for research are being reduced. Most importantly, public audiences can challenge science and serve as a source of new perspectives and new questions. How does this engagement take place?

In considering models of interaction through which experts communicate with public audiences, Larry Bell from the Museum of Science explained multiple dimensions of these interactions that lead to different outcomes (Fig. 3). The first dimension is the topic or focus of the interaction and includes the range of possibilities shown in the top row. The second dimension, shown in the middle row, is the way in which public participants engage with the topic. The third dimension, shown in the bottom row, is the way in which experts such as scientists or engineers engage with the topic and the public. Together, these three dimensions create a spectrum of roles and formats through which scientists, educators, and public audiences consider science and its societal impacts.

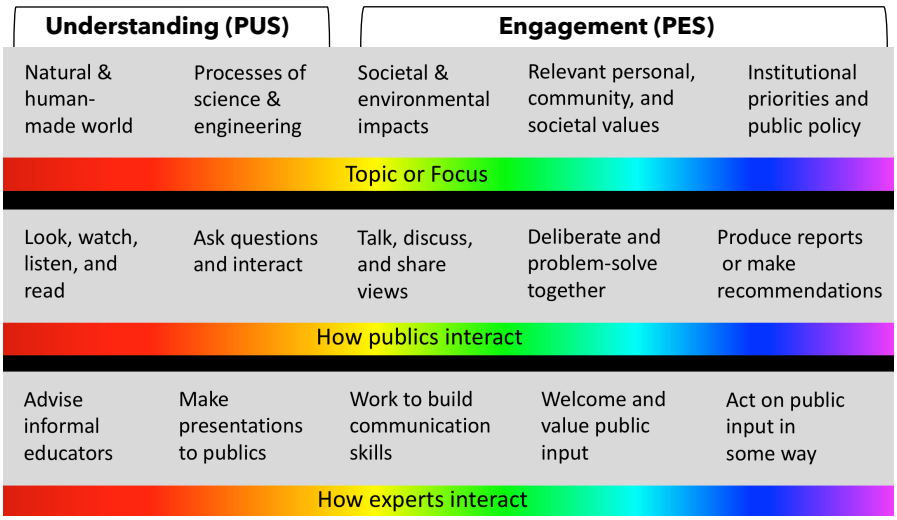

Figure 3. Dimensions of public-expert interactions with topics in science.

Bell described the two left columns of the spectrum as likely to be most familiar to those working in informal science education or who do public outreach. These fall under the umbrella of "public understanding of science" (PUS), where the goal may be to demonstrate a phenomenon, build excitement about science and its benefits, or inform about an issue. However, science is not just about facts and phenomena. The relevance of science comes from its application to people's lives, our communities, our country, and the world. In a report from the Center for Advancement of Informal Science Education, McCallie et al. (2009) termed this "public engagement with science" (PES). These interactions, which include diverse perspectives and can influence behavioral change in multiple audiences, are represented in the three right columns of the spectrum.

Given the rapid advancement of neuroscience in many areas affecting our society, the field is at a crossroads where public interest is high and public involvement is essential. As Jensen reflected, neuroscience is a relatively new field of biological and social science; in fact the term "neuroscience" did not exist fifty years ago. Most adults know very little about how the nervous system functions, yet low quality information abounds in popular culture. There is certainly a need for outreach on the PUS end of the spectrum to correct these gaps in knowledge and especially to debunk pervasive "neuromyths."

Modern neuroscience is unique among STEM topics in its personal, community, and societal relevance, making it a particularly good fit for public engagement and dialogue.

However, neuroscience is relatable, and knowledge about neuroscience can improve people's quality of life with its implications for health, wellness, and recognition of disease. As the brain is a hidden organ, new technologies are revealing its structure and function, and input from public audiences is essential in determining how and when insights from these technologies are integrated into our everyday lives. These characteristics of neuroscience should motivate us to push our outreach efforts towards PES activities. A central focus of this conference, therefore, was considering the diverse societal impacts, values, and choices that are informed by neuroscience in order to identify how to best engage scientists and public audiences in meaningful dialogue.

EXISTING NEUROSCIENCE OUTREACH ASSETS

Any future neuroscience public engagement project will benefit from leveraging the strong base of existing assets in neuroscience education and public outreach. Building on this foundation, a cohesive effort to identify and communicate key messages about neuroscience and strategies for addressing societal impacts will lead to successful public engagement, as well as improved efficacy, broader reach, and deeper expertise of participating professional audiences.

BrainFacts.org and Neuroscience Core Concepts

Nick Spitzer, the founding editor-in-chief of *BrainFacts.org*, led the group in reviewing this essential resource for neuroscience education, a public information initiative of SfN, The Kavli Foundation, and the Gatsby Charitable Foundation. This comprehensive website is regularly updated and reviewed for accuracy by SfN members or by trusted content partners approved by the *BrainFacts.org* editorial board.

The site content is organized around eight Neuroscience Core Concepts (Fig. 4). These concepts were first developed by SfN in 2007, through consultation with neuroscientists and educators, and serve as a starting point for considering the brain and nervous system as content for activities and inquiry in educational settings. Each essential principle is supported by fundamental concepts comparable to those underlying the U.S. Next Generation Science Standards.

In conjunction with a strong framework for science learning outcomes, conference attendees agreed that these key science content ideas can serve as a starting point for organizing an informal neuroscience education initiative. Potential educational experiences can be designed to focus on different concepts and offer different learning experiences, as appropriate for specific target audiences, formats, and topics.

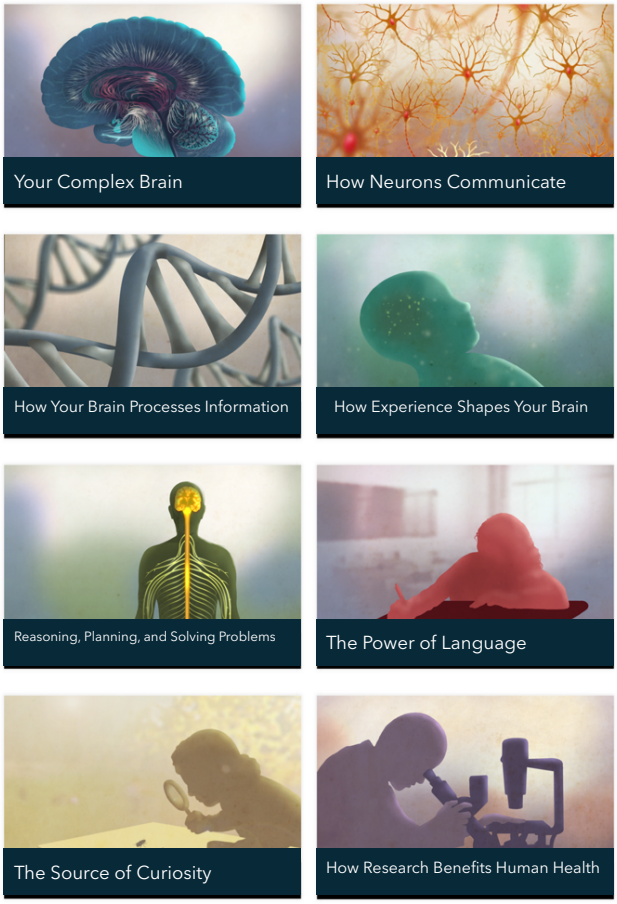

Figure 4. Neuroscience Core Concepts, developed by *BrainFacts.org*.

Current neuroscience public outreach

The group then discussed the landscape of present neuroscience outreach efforts with a focus on levels of public-expert interactions to identify where, if at all, there were needs for additional or different kinds of outreach.

Kathleen Roina from The Dana Foundation and Alissa Ortman from SfN described the scope of Brain Awareness Week (BAW), an annual global outreach campaign. BAW was founded in 1985 by the Dana Alliance for Brain Initiatives to increase public awareness about brain research. Today, with support from SfN, BAW continues to be a celebration of brain science every March and serves as the highlight of year-round public outreach. The goals of BAW include increasing visibility of partner organizations in the context of a global education initiative, spreading the word about the importance of brain

research, arming the public with knowledge to make informed health decisions, and inspiring the next generation of scientists. BAW partners organize events and activities for families, schools, and communities. However, there is relatively little overlap between current BAW partners and informal science institutions in the NISE Network, suggesting an ideal opportunity to build new partnerships and reach new audiences.

Box 2: Examples of current neuroscience outreach efforts

- Brain Awareness Week
- Science for Monks
- braiNY (New York University)
- Science Club (Northwestern University)
- Neuroscience Boot Camp (University of Pennsylvania)
- Living Laboratory
- Neurodome
- Neuroscience for Kids

While BAW is perhaps the most visible, coordinated public outreach effort, conference attendees shared a number of additional programs with different formats and audiences, including those listed in Box 2. The group also discussed the expertise of health-related support organizations such as those serving patients affected by different diseases and disorders, parents and caregivers of young children, advocates for mental health, and others. Many of these organizations have active community networks and educational resources for helping the public make informed decisions about their health.

There is an unmet need to push beyond core concepts and promote collaborative learning between scientists and public audiences around the societal impacts of neuroscience.

As the group reflected on these programs in the context of the public-expert interactions discussed earlier, a consensus emerged that there is a need that goes beyond merely connecting informal science institutions and their audiences with existing efforts. The current neuroscience outreach landscape favors the PUS side of the spectrum, with a focus on countering neuromyths, explaining foundational principles and phenomena, and promoting brain health and safety. How can we shift the landscape towards more bidirectional, PES-type interactions that foster an exchange of ideas between scientists and public audiences around the rapid and unique advancements of modern neuroscience?

Informal STEM learning frameworks

Research-driven learning frameworks in informal STEM education can scaffold more advanced levels of engagement with the public. Elizabeth Kollmann from the Museum of Science presented several examples that demonstrate the potential of informal science education to promote science learning beyond specific science content. The National Research Council (2009) has identified six evidence-based strands of learning in informal environments (Fig. 5). These strands describe cognitive, social, developmental, and emotional elements of participation, recognizing that encounters with science in out-of-school environments can be particularly effective in stimulating interest and building science learning identities. Similarly, the Institute of Museum and Library Services (2009) has defined a set of

21st century skills that museums and libraries are well suited to nurture. These include skills in learning and innovation; information, media, and technology; life and career skills; and emerging global themes in civic, health, and environmental literacy.

Learners in informal environments...	
	Experience **excitement, interest, and motivation** to learn about phenomena in the natural and physical world.
	Come to **generate, understand, remember, and use** concepts, explanations, arguments, models, and facts related to science.
	Manipulate, test, explore, predict, question, observe, and make sense of the natural and physical world.
	Reflect on science as a way of knowing; on processes, concepts, and institutions of science; and on their own process of learning about phenomena.
	Participate in scientific activities and learning practices with others, using scientific language and tools.
	Think about themselves as science learners and **develop an identity** as someone who knows about, uses, and sometimes contributes to science.

Figure 5. Strands of learning in informal environments that support public engagement with science. National Research Council (2009).

As demonstrated by several NISE Network projects, these evidence-based frameworks can help establish goals that go beyond content learning. For instance, the design principles for a project on Earth and space science encourage the development of engaging, authentic, current, relevant, and accessible experiences that incorporate real phenomena, the scientific process, and community participation. Another project focuses on increasing positive attitudes towards chemistry by designing experiences that increase learners' interest in chemistry, understanding of its relevance, and feelings of self-efficacy. For a third project on synthetic biology, the Network expanded its framework beyond its goals for public learners to develop specific goals for participating scientists around exploring their personal and societal values and developing skills in facilitating conversations. More information on these projects can be found in Appendix B.

Research in informal learning can be applied to neuroscience to guide the development of experiences that complement each other in achieving learning goals that cover science and society, interest and engagement, skills, relevance, self-efficacy, and even goals for audiences beyond the public. In addition, such a framework would establish a set of benchmarks against which the resulting products and activities can be evaluated.

Informal learning research can be applied to neuroscience to achieve science and society learning goals.

NISE Network and Informal STEM Education Assets

To build the capacity of the informal science education field in facilitating more programs towards the PES end of the interaction spectrum, the NISE Network, in collaboration with the Center for Nanotechnology in Society at Arizona State University, has created strategies for stimulating discussion and deliberation about values and priorities associated with STEM topics. Larry Bell, Catherine McCarthy from the Science Museum of Minnesota, and other NISE Network team members described how the Network has implemented these public engagement strategies in a variety of educational products, including media, short activity toolkits, stage presentations, exhibitions, and forums (Box 3).

Box 3. Examples of NISE Network educational products for informal learning

Program toolkits: short hands-on activities or games, presented at a table, cart, or demonstration space by a facilitator, lasting less than fifteen minutes for families and small groups of people.

Stage presentations: delivered to large groups of people in a dedicated presentation area or stage

Media: short scripted videos for either public or professional audiences

Exhibitions: unstaffed experiences, including hands-on interactive components, multimedia, object displays, and graphic panels.

Forums: one- to two-hour facilitated discussions for older youth and adults focusing on a socio-scientific question.

Media for public audiences are both entertaining and thought-provoking, while those for scientists and educators are created for training in facilitating conversations where there is no right answer and the public's views are welcome. Program toolkits and stage presentations often involve simple interactive materials that help public audiences consider their own values as well as those of others, and can be personalized by the facilitator for each group of participants.

Though NISE Network mini-exhibitions are just 400-500 square feet in size, these exhibitions have a large national reach (for example, over 10 million visitors per year visit the 93 copies of the *Nano* mini-exhibition) including geographically diverse audiences and smaller communities. As an example of how exhibitions can facilitate public engagement, *Nano* applies a PES approach to include questions about applications of nanotechnology, its possible societal benefits and risks, and the balance between nano and society in the fun, social, and interactive learning experiences that draw audiences to the exhibition.

Forums foster dialogue and deliberation and are explicit in the expectation that public participants have valuable knowledge to share. Shared background knowledge, often presented by experts, is used to frame the conversation, and multidirectional conversations bring in diverse perspectives, including those of scientists. The resulting views are reported out to the entire group and can also be shared with external stakeholders.

Robust professional development networks

Any dialogue about science between public audiences and experts obviously requires the participation of scientists. There are many models of successful partnerships between scientists and informal science institutions that have yielded valuable outcomes for professionals on both sides. As Darrell Porcello from the University of California Berkeley shared, these partnerships have been a critical component of NISE Network projects. Among Network partners involved with a project on nanoscale science and technology, 78% reported that they collaborate with other organizations to engage the public. Of these partners, 80% reported they collaborated with STEM professionals universities or colleges and 29% partnered with STEM professionals in industry (Goss et al. 2016).

The NISE Network develops resources for professional audiences such as online workshops, in-person meetings, programs, and guides. For educators, these opportunities enable them to identify with a broader community of professionals, increase their pedagogical and STEM content knowledge, and spark new and valuable local collaborations. Opportunities targeted to scientists help them develop their communication skills with the public, share their work and passion, and build public support for and understanding of research. For example, in the Network's synthetic biology project, participating scientists not only reported increased confidence in their ability to engage the public, but also learned about the public's values and felt that visitors contributed to discussions addressing the societal and/or ethical implications of science (Rockman et al. Research and Evaluation, 2018).

For a potential informal neuroscience education project, the Society for Neuroscience's robust professional development network for scientists is an invaluable asset. Alissa Ortman gave the group a virtual tour of Neuronline, SfN's member portal for professional development, which hosts videos, webinars, podcasts, articles, and discussion forums on outreach, communication, and advocacy. These online resources complement regular in-person sessions on these topics at the annual SfN conference and support connections between scientists and educators through the "Find a Neuroscientist" database. With these resources already in place, any professional development opportunities for scientists that emerge from a new public engagement project can reach their target audience quickly and effectively.

PROJECT VISION

Summarized in the sections above, the first part of the conference was designed to survey the fields of neuroscience, neuroscience outreach, and informal science education, identify common themes, and determine assets and needs. In the second part, after absorbing and discussing this rich foundation, conference participants came together to build a vision for a future neuroscience public engagement project that would leverage the diverse strengths of the national organizations and supporting partners represented at the meeting.

As emerging neuroscience revolutionizes how we see the human brain, we are at a critical point at which to promote sustained public engagement around the personal, community, and societal impacts

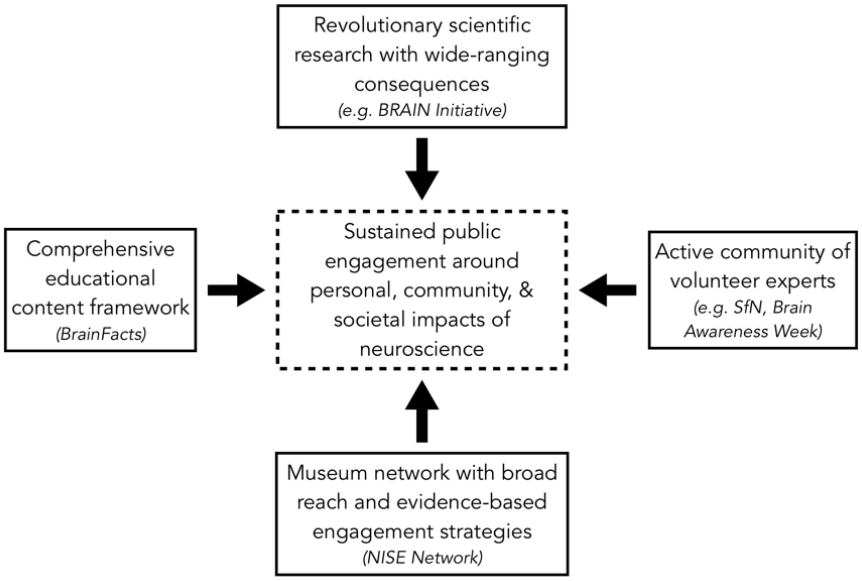

Figure 6. A novel opportunity for sustained public engagement will leverage the strengths of the current neuroscience outreach ecosystem.

of neuroscience. The current neuroscience outreach ecosystem (Fig. 6) has many of the necessary components in place: a rapidly growing field of science with intrinsic public interest, an educational content framework, an active community of volunteer experts promoting public understanding of neuroscience, and a national museum network with evidence-based strategies for public engagement. At the intersection of these components arises a unique opportunity to bring public audiences into the conversations and decision-making processes that are pushing neuroscience forward.

Organized by the NISE Network, the **National Informal Neuroscience Education (NINE) Initiative** will be designed to increase the capacity of both museums and scientists to connect the public to the science, technology, and societal implications of neuroscience. Grounded in a core of cohesive science content that communicates key messages of the field, the NINE Initiative will develop PES products that expand and leverage existing partnerships between scientists, museum, and community organizations to reach diverse audiences.

The significance of an intentional PES approach emerged as conference participants considered the needs and values that are shaping the trajectory of current neuroscience research. From individual habits of sleep, diet, and exercise to the social stigma of mental illness to the business of artificial intelligence, applications of neuroscience touch almost every aspect of our lives. There are choices to be made at every level: personal choices made by individuals; choices made by parents, caregivers, and educators on behalf of children; economic and corporate choices; societal choices and priorities for funding; and equity and access to resources. Fig. 7 shows a word cloud representing a brainstorm of the range of potential impacts of emerging neurotechnologies on our society.

These technologies open up new possibilities, shape our relationships, promote the values of those who build them, and through a variety of systems affect many different parts of our society and communities. At its core, this potential project will aim to illustrate that while new technologies will help shape our future, people everywhere have opportunities to influence what that future looks like.

Figure 7. Societal impacts of emerging neurotechnologies. Conference attendees brainstormed how neuroscience plays a role in individual choices, caregiver decisions, economics and industry, societal norms, and equitable access to resources.

Potential target audiences

Through its network of over 600 partner organizations, including approximately 400 science centers, science museums, and children's museums, the NISE Network reaches a core public audience of millions per year. These intergenerational family groups generally consist of children (primarily in preschool through middle school) accompanied by one or more adults, including parents, grandparents, and other caregivers. Many Network partners also target adult audiences through special programs such as discussion forums and after-hours events. The discussion of societal impacts brought to the forefront the ways that neuroscience informs individual, family, and community choices relevant to health, technology, social relationships, and more. Attendees agreed that reaching social groups across generations would be a vital approach for the NINE Initiative in order to include multiple perspectives, encourage discussion, and perhaps even inspire collective action.

Professional audiences are also a target for this project. As previous NISE Network projects have shown, collaborations between scientists and informal science educators result in learning outcomes for both (Goss et al. 2016). The NINE Initiative will aim to increase capacity for brain-related programming in science and children's museums by training educators in neuroscience content. There are also unique learning outcomes for scientists gained from their interaction with public audiences (Svarovsky, Tranby et al. 2015; Rockman et al. Research and Evaluation 2018). To promote these outcomes, the project will also build communications skills in the active community of volunteer neuroscientists, particularly with respect to public engagement through facilitating conversations about values, priorities, and societal impacts.

Project focus

In developing a vision for the NINE Initiative, conference participants identified four strands of potential focus to consider in determining the goals of the project: **science content and learning frameworks, public engagement, audiences and inclusion, and professional development**. During the conference, participants divided into small groups—bringing together common interests and expertise from both the neuroscience and informal science education communities—to brainstorm how each strand could shape the initiative. With distinct goals but obviously overlapping strategies,

these strands will guide the definition and development of a suite of products that collectively lead to the full range of outcomes.

Science content and learning frameworks

The strength of neuroscience as a topic in science education is that learning about the brain inevitably generates excitement about how to apply that learning to ourselves and the world around us. Conference attendees discussed both key science concepts and affective science learning goals, and agreed that the social and emotional connections should guide the science content in any neuroscience public engagement project. Experiences should: 1) be participatory – engaging people in using and reflecting on their own brains, 2) be relevant – connecting to personal and timely issues, 3) inspire wonder – imagining new ideas made possible by the brain's incredible complexity, and 4) empower behavioral change – providing strategies and resources to make more informed choices.

As conference participants aligned these goals with the *BrainFacts.org* core concepts, several topics from the framework emerged as potential primary areas of focus. *Plasticity* incorporates many fundamental concepts of neuroscience within the context of how the brain changes across many time scales. *Learning and memory* are practical concepts that are immediately applicable to learners of all ages and abilities. *Health applications*, defined broadly from wellness to disease, illustrate the relationship between the brain and body. *Evolution* addresses both what makes us human as well as the marvelous diversity of brains among living things.

There are also broader themes about the process of science that are embedded in neuroscience. How do we know what we know about the brain? There are many opportunities for people to use self-assessment in experimenting with their own brain functions, collecting data, and comparing to others. Critical thinking skills are essential for interpreting and applying these results or for assessing the validity of neuromyths and other popular ideas about the brain. Finally, the technological tools and interdisciplinary connections in neuroscience are reflective of how modern science continually asks new questions and solves problems. As new products and programs are developed, these elements of the scientific process should be integrated into how audiences are introduced to the science content.

Public engagement

To facilitate dialogue around the personal, community, and societal impacts of neuroscience, conference attendees suggested that the NINE Initiative should draw upon evidence-based best practices of public engagement. Scientists and educators should both literally and figuratively meet people where they are. Design strategies supporting effective engagement include learning experiences that are fun, social, and active, engaging multiple senses and provoking curiosity. The overall message of the project should lead with a topic that generates optimism, while connecting to current events or more serious issues of community relevance, such as concussion, addiction, or stress. Strategies for increasing individual efficacy ("how can I avoid/improve/prepare for…") should be integrated across all elements of the project.

Mutual trust between scientists and public audiences is also critical for effective engagement. The group suggested that to build trust, learning experiences should emphasize the human aspects of neuroscience by promoting an exchange of values between scientists and the public, encouraging

scientists to share their values through compelling stories. How are neuroscientists trying to solve societal challenges? What are the personal motivations behind their work? Scientists should also be open to discussing both positive and negative implications of neuroscience research and its applications. Discussions of ethics should bring in not just the perspective of scientists but also lawyers, physicians, religious leaders, patients, and others.

Given the potential for emerging neuroscience to transform society, the NINE Initiative also offers opportunities to move beyond engagement and inspire people to take action. Conference attendees suggested that one approach could involve coordinated citizen science efforts around a particular research question. What might researchers want to learn about the brain—or about the ethical dimensions of neuroscience research—with the help of a large, diverse, and interested segment of the public? The NINE Initiative could also coordinate nationwide forums aimed at gathering public opinions and values to inform decisions made by the research community or by policy makers. Perhaps the most exciting, but also challenging, idea that emerged was the concept of facilitated dialogues that could shift individual and collective attitudes about societal issues and the implications of brain science. For example, what do we define as "normal" in terms of mental health and ability?

Audiences and inclusion

The personal relevance of neuroscience makes it an ideal topic to engage a diversity of public audiences. From young children to teens to senior citizens, the human brain is interesting and relevant across the lifespan. In addition, conference attendees felt that the social dimensions of neuroscience create opportunities to cut across divisions in socioeconomic status, gender, language, geography, and ability. Integrating these sociocultural factors with science content—whether through co-development with target audiences, representation in educational products, or both—is especially critical because the neuroscience community, as a whole, is not reflective of the diversity of the general population. Through past projects, the NISE Network has developed specific strategies and resources for engaging and including learners of all levels and backgrounds that will inform the design of products for the NINE Initiative.

A new challenge for this project would be to develop strategies for engaging audiences as both learners and experts. Neurodivergent people, older adults, patients who may be affected by new treatments, and others are all experts in their own experience but are also uniquely motivated to learn about the science that impacts their lives. How can these individuals' perspectives be woven into a social learning experience?

The broad implications of emerging neuroscience are also likely to be of interest to audiences who may not visit museums and informal science education institutions. The group suggested that a key element of the NINE Initiative would be to develop new collaborations between Network partners and organizations that serve these under-engaged community sectors, such as children's hospitals, adult care facilities, health support groups, or youth organizations. The project will leverage and extend Network partners' creative approaches for reaching non-traditional audiences (past efforts have ranged from flash mobs in community spaces to programs for incarcerated parents and their children).

Professional development

As described in the existing assets of the neuroscience outreach ecosystem, a rich variety of expertise is in place to shape the development of the NINE Initiative. Conference attendees reflected on how bringing these different expert communities together could create an opportunity to build a model of shared learning between scientists, informal science education professionals, and public audiences. Scientists can contribute science content and the broader context of the grand challenges that are being tackled in the field. Educators can contribute communication skills and best practices for learning, while public audiences contribute the individual context and neurodiversity that brings personal meaning to the science.

There are many aspects of science content and science communication that are critical for building capacity for neuroscience public engagement. The science of learning and memory is an important foundation for outreach. Successful facilitation includes being able to address common misconceptions, guide inquiry, and develop programs accessible to diverse audiences. Encouraging learners to share personal experiences and navigating reactions to weightier topics also requires sensitivity and skill. The group suggested that these topics could be addressed in professional development components of the NINE Initiative, with opportunities for co-learning through a mix of online and in-person trainings, and rapidly deployed using existing NISE Network and SfN infrastructure.

For the broader outreach community, scientists and educators at the conference also identified the need for an online repository of curated, vetted, and easily updated resources for outreach and education. Given the dynamic, rapidly changing nature of neuroscience, this catalog would prioritize the most relevant and successful outreach products, linked to core concepts and current research translated for practitioner use. Existing resources from *BrainFacts.org* and the Dana Foundation could be tapped for this supporting content.

NEW PARTNERSHIPS FOR A NEW APPROACH

Recognizing that "ethical and societal questions are not questions for experts alone" (Yuste & Bargmann 2017), leaders of international brain research initiatives have emphasized that citizens must be engaged in discussions about the development and application of emerging neuroscience as an essential component of a global research initiative. This type of public engagement requires a new model of outreach; a workshop convened by the Organization for Economic Cooperation and Development identified a "need for experimentation and examples of governance and public deliberation approaches across sectors" (Garden et al. 2016).

The brain is always changing. How will neuroscience outreach also change?

To meet this need, the NINE Initiative represents an innovative opportunity for partnership between the neuroscience community and informal science institutions to promote sustained public engagement around the personal,

community, and societal impacts of neuroscience. With its existing national infrastructure and experience in developing PES products for public audiences, the NISE Network is well positioned to lead this effort, while the active involvement of SfN, the Dana Foundation, ASTC, and other key stakeholders will be essential to integrate existing neuroscience research and outreach communities. The logic model in Fig. 8 summarizes how the synergy between these assets and expertise can lead to both professional and public outcomes advancing a conversation around the societal and ethical impacts of neuroscience.

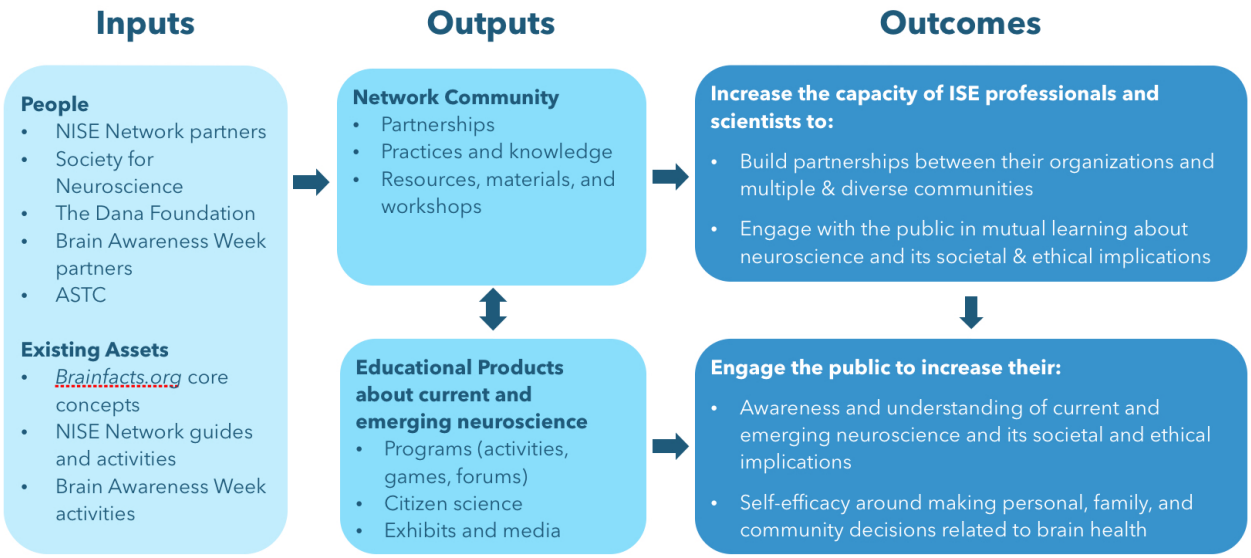

Fig. 8. Proposed framework for the NINE Initiative. The project could leverage existing assets and expertise to generate new partnerships and products supporting a novel approach to public engagement with neuroscience.

As the group considered the intersection of different strands within the NINE Initiative, an overarching theme also emerged to guide the project forward: **neuroplasticity**. The perception of the brain as an adaptable, responsive control center of the body could support many of the PES outcomes listed in the framework above. From a science content perspective, this core concept of change is critical to understanding how the brain functions. Beyond the science, neuroplasticity is relevant to audiences of all backgrounds in considering how life experiences affect brain development. It builds an appreciation of neurodiversity, demonstrates personal agency over learning, health, and development, and influences the choices we make for ourselves and for our families. It impacts the societal applications of neuroscience, from courtroom decisions to cognitive neuroenhancement to the development of brain-machine interfaces. This unifying concept—that the brain is always changing—is therefore an ideal message to anchor a public conversation about the future of neuroscience in our world.

With this thoughtful and inclusive vision for public engagement with neuroscience, the NISE Network next aims to connect with stakeholders and funders in both the informal science education and neuroscience research communities.

Build grassroots momentum

As previously described, NISE Network partners have already expressed significant interest in the general topic of brain science, and we can collect additional input on priorities for the informal science education field through regular channels of communication with partners, such as ASTC and Association of Children's Museums conferences or the annual NISE Network partner survey.

For neuroscientists, the Brain Awareness Week campaign event at the 2017 annual Society for Neuroscience conference featured a keynote presentation by Jayatri Das, chief bioscientist at The Franklin Institute. The presentation highlighted how science museums can help bring current science to a broader range of audiences, increase capacity by supporting year-round programs, and foster meaningful dialogue about the societal impacts of emerging science. The enthusiastic response from the audience indicated that the presentation was successful in raising awareness among scientists of the benefits of working with informal science education institutions, and we anticipate that new partnerships may begin to emerge through future Brain Awareness Week programs.

These initial efforts demonstrate that there is significant grassroots interest within both the neuroscience and informal science education communities to support a broader collaborative initiative around public engagement. We will reach out to stakeholder communities to collect feedback on the potential development of materials suitable for museum audiences to increase public understanding, engagement, and dialogue with scientists around relevant neuroscience topics.

Connect with research initiatives

With growing recognition in the scientific community that public engagement is a necessary component of responsible research, the NISE Network seeks to build relationships with formal research initiatives such as the BRAIN Initiative Alliance and the International Brain Initiative, facilitated by The Kavli Foundation. In April 2018, NISE Network partners collaborated with the Foundation at an event in Washington DC in celebration of the 5th anniversary of the U.S. BRAIN Initiative. This event offered the opportunity to communicate the value, through hands-on activities and demonstrations, of public outreach and engagement to BRAIN Initiative investigators, congressional staff, advocacy organizations, and other stakeholders in neuroscience research.

Engage additional stakeholders and seek project funding

The NISE Network has a proven track record of creating high-quality products for museum audiences, including hands-on activities, longer-format programs, educational media, exhibitions, and professional development trainings for both scientists and museum educators that reach millions of people each year. These products are developed in collaboration with scientists, and research and evaluation have demonstrated their transformative impact. The Network will seek the support of potential funders to enable the co-development, production, and dissemination of these elements through the NINE Initiative. These stakeholders could include federal agencies (such as the National Science Foundation or the National Institutes of Health) as well as philanthropic and advocacy organizations with mutual interests in engaging scientists and public audiences around the societal impacts of emerging neuroscience.

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APPENDIX A: CONFERENCE AGENDA AND PARTICIPANTS

Planning and Partnerships Conference for Neuroscience Public Engagement
January 16-18, 2018
The Franklin Institute

Agenda for Tuesday, January 16

5:00 pm	Arrive and check in at The Franklin Institute Explore *Your Brain* exhibit and floor programs during Community Night (monthly event at The Franklin Institute with free museum admission)
6:30 pm	Introductions and dinner
7:30 pm	Outreach showcase: Each project/person gives a 2-minute introduction, followed by informal conversations & browsing resources
8:30 pm	Day 1 concludes

Agenda for Wednesday, January 17

9:00 am	Welcome and charge for the day Jayatri Das, The Franklin Institute
9:15 am	Introduction to the National Informal STEM Education Network Paul Martin, Arizona State University Rae Ostman, Arizona State University
9:55 am	Overview of Current Brain Science *Discussion: What are the fundamental questions and emerging research directions in neuroscience?* Frances Jensen, University of Pennsylvania
10:35 am	Spectrum of Public Engagement with Science *Discussion: What opportunities and challenges does neuroscience offer for PES?* Larry Bell, Museum of Science Darrell Porcello, University of California, Berkeley
11:35 am	Break
11:45 am	Professional Development *Discussion: What are PD needs in neuroscience for scientists & ISE professionals?* Alissa Ortman, Society for Neuroscience Darrell Porcello, University of California, Berkeley

12:15 pm Lunch

1:15 pm Concept Maps and Learning Frameworks
Discussion: What kinds of learning do we want to promote? How might the BrainFacts Core Concepts and PES ideas form the basis of a learning framework? What other kinds of learning might we focus on, beyond content knowledge?
Elizabeth Kollmann, Museum of Science
Nick Spitzer, University of California, San Diego

2:00 pm Visioning Activity
How do we build on content-based framework to explore broader opportunities in ISE?
Science content and learning frameworks
Public engagement
Professional development
Audiences and inclusion

2:15 pm Small group breakout to draft goals and identify strategies for each area

3:15 pm Break

3:30 pm Share key goals for whole group discussion and refinement

4:15 pm Plenary discussion
Establish concrete recommendations from the meeting group
Preliminary discussion of how to develop these ideas into a collaborative project (to be refined the next day by smaller group)

4:45 pm Wrap-up and next steps

5:00 pm Day 2 concludes

Agenda for Thursday, January 18 (small group only)
The Franklin Institute, Fifth Floor Conference Center

9:00 am Small group meeting to develop action plan
NISE Net: Larry Bell, Paul Martin, Rae Ostman, Jayatri Das, Darrell Porcello, Catherine McCarthy, Elizabeth Kollmann
Kavli Foundation: Eric Marshall, Brooke Smith, Caroline Montojo
SfN: Alissa Ortman

11:00 am Conference concludes

Conference Participants

Afterschool Alliance	Melissa Ballard	STEM Manager
Arizona State University	Ira Bennett	Associate Director for Research, School for the Future of Innovation in Society
Arizona State University	Paul Martin	Co-Director, Center for Innovation in Informal STEM Learning
Arizona State University	Rae Ostman	Associate Research Professor, School for the Future of Innovation in Society
Association of Science-Technology Centers	Margaret Glass	Director, Professional Development
Dana Foundation	Kathleen Roina	Director, Brain Awareness Campaign
Dana Foundation	Ann Whitman	Director, Marketing & Communications
The Franklin Institute	Jayatri Das	Chief Bioscientist
The Franklin Institute	Karen Elinich	Director of Science Content & Learning Technologies
The Franklin Institute	Andrea Foster	Project Assistant
The Franklin Institute	Julia Skolnik	Assistant Director of Professional Development
Howard Hughes Medical Institute	Boyana Konforti	Director of Scientific Strategy & Development
Kavli Foundation	Eric Marshall	Vice President, Prizes and Public Programs
Kavli Foundation	Caroline Montojo	Science Program Officer
Kavli Foundation	Brooke Smith	Director of Public Engagement
Marbles Kids Museum	Hardin Englehardt	Director of Community Engagement
Museum of Science	Larry Bell	Senior Vice President for Strategic Initiavies
Museum of Science	Elizabeth Kollmann	Senior Project Manager, Research and Evaluation
National Girls Collaborative Project	Karen Peterson	Chief Executive Officer
New York University	Heather McKellar	Senior Manager of Education and Outreach, Neuroscience Institute
Northwestern University	Michael Kennedy	Research Professor of Neurobiology and Director of Science in Society
Science Museum of Minnesota	Catherine McCarthy	NISE Network Project Leader
Sciencenter	Ali Jackson	Director of National Collaborative Projects

Society for Neuroscience	Lisa Chiu	Director, Neuroscience Literacy & Managing Editor of *BrainFacts.org*
Society for Neuroscience	Alissa Ortman	Outreach & *BrainFacts.org* Manager
UC Berkeley	Darrell Porcello	NASA Co-Investigator & NISE Network Senior Project Manager
UC San Diego	Nick Spitzer	Distinguished Professor of Neurobiology
University of Pennsylvania	Martha Farah	Director, Center for Neuroscience & Society
University of Pennsylvania	Hilary Gerstein	Associate Director of Education, Center for Neuroscience & Society
University of Pennsylvania	Roy Hamilton	Director, Laboratory of Cognition & Neural Stimulation
University of Pennsylvania	Frances Jensen	Professor of Neurology and Chair, SfN Public Education & Communication Committee
University of Washington	Eric Chudler	Executive Director, Center for Sensorimotor Neural Engineering

APPENDIX B: EXAMPLES OF NISE NETWORK PROJECTS AND LEARNING FRAMEWORKS

Sun, Earth, Universe Exhibition
50 free exhibitions in 2018 and 2019

The *Sun, Earth, Universe* exhibition is an engaging and interactive museum exhibition about Earth and space science for family audiences.

Learning framework:
- Audiences will experience Earth and space phenomena and explore scientific discoveries.
- Audiences will use the scientific process and reflect on science as a way of knowing.
- Audiences will participate in the scientific community and identify as a science learner.

Explore Science: Let's Do Chemistry
250 free kits of educational activities in 2018

The hands-on, interactive kits about chemistry encourage observation of phenomena, experimentation with variables, and connections to everyday life.

Learning framework:
- Participants will have an increased interest in the field of chemistry.
- Participants will have an increased understanding of the relevance of the field of chemistry to their lives.
- Participants will have increased feelings of self-efficacy about chemistry (their ability to do chemistry activities and participate in conversations about chemistry).

Building with Biology
200 free kits of educational activities in 2016

The hands-on, interactive kits and public forum programs are designed to promote conversations among scientists and public audiences about synthetic biology.

Learning framework:
- Public audiences will engage with scientists and engineers in conversations about what synthetic biology is, how research in the field is carried out, and the potential products, outcomes, and implications for society of this work.
- Researchers and publics will explore personal and societal values and priorities as well as research outcomes so that both groups can learn from each other.