DEMOCRATIZING NANOTECHNOLOGY: THE NANOSCALE INFORMAL SCIENCE EDUCATION NETWORK AND THE MEANING OF CIVIC EDUCATION

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DEMOCRATIZING NANOTECHNOLOGY: THE NANOSCALE INFORMAL SCIENCE EDUCATION NETWORK AND THE MEANING OF CIVIC EDUCATION

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This dissertation explores how informal science educators create scientific knowledge rather than merely reformulating or reorganizing it, using research based on an ethnographic study of the first five years of the Nanoscale Informal Science Education (NISE) Network, which began in 2005. The Network was the first large-scale informal science education network of science museums and centers funded by the National Science Foundation to focus on an emerging technology. I demonstrate how informal science educators occupy as powerful a position as scientists in defining emerging science and technology and the implications of that position for civic education and learning.

The NISE Network and its relationship with the National Science Foundation play significant roles in defining the type of learning and educational approaches to emerging technologies that are trusted by the field of informal science education at large. This dissertation demonstrates how the challenge of an unfamiliar subject (nanotechnologies) and unfamiliar methods (networking, distribution, and evaluation) shaped the Network's approaches to education and learning. The three case studies of this dissertation, which were also the three primary programming efforts of the NISE

Network in those first five years, demonstrate the compromises and negotiations the Network made in order to fulfill its obligations to NSF.

Chapter 2 concludes that although informal science education (ISE) as a whole has an interest in and a use for art methodologies applied to science education, ISE as defined by the NSF has not yet settled on the best way to incorporate such methods and knowledges into its practices. Chapter 3 demonstrates the constraints of spreading knowledge through a diversified, but professionalized network of informal science educators. The historical legacy of the field of ISE situates it within specific expectations and practices which shaped individual interpretations and assumptions about the best methods for the NISE Network to use in presenting nanotechnologies. Chapter 4 further identifies that which is currently being negotiated in the field of informal science education by looking at how professional practices and civic epistemologies help define the role of the science museum and the ISE field in civic education and democratic society.

BIOGRAPHICAL SKETCH

Kathryn DuShane Vignone attended Riverside High School in Greer, South Carolina. She received the only degree awarded directly by the Honors College of the University of South Carolina, Baccalaureus Artium Scientiae in 2005. It was during the completion of her Honors Thesis under the direction of Professor Chris Robison that she began to consider how knowledge about emerging technologies is made public. She completed her Ph.D. on the relationship between civic education and a public understanding of nanotechnology in the Department of Science & Technology Studies under the direction of Dr. Bruce V. Lewenstein at Cornell University in 2013. At the time of this dissertation's completion, she was serving as a postdoctoral fellow in the Center for Nanotechnology in Society at Arizona State University.

FOR KAREN

WHO STARTED ME ON THIS JOURNEY

AND ANTONIO

WHO ACCOMPANIED ME

ACKNOWLEDGMENTS

As I conclude this dissertation, I am only now fully beginning to realize that this resolution signifies both the end and the beginning of an era in my life. I continue to be grateful to the many important people have punctuated this era.

From my time at the University of South Carolina I am indebted to Drs. Ed Munn, Peter Sederberg, Leslie Sargent-Jones, Catherine Murphy, Lance Paulman, Don Greiner, Chris Toumey, Rudy Manke, Fausto Pauluzzi, and Harry Miller for seeding my interest in and passion for learning while helping me to figure out how to find a way for my often nontraditional approaches to learning to fit into traditional expectations. It was their work, lives, and attitudes that made the prospect of a doctoral degree and a professorial career appealing. Most importantly though, this dissertation and my career (or at least what there is of one thus far) would not have even been possible without the ongoing support, encouragement, and critique of professor and artist Chris Robinson. He has been my unwavering supporter beginning at USC and continuing throughout my graduate study and I will never be able to fully repay the kindness. My first publications are intellectually and procedurally a result of his presence in my life.

The members of my dissertation committee at Cornell were instrumental in my completion of this dissertation. Professor Ron Kline served as an unfailing supporter of my interest in the history of technology and provided countless career advice and support. I am indebted to Professor Michael Lynch for his mentorship, friendship, and guidance, as I bumbled my way from ignorant first year graduate student to co-author and friend. Even now, Mike continues to help me develop my professional goals and interests, often over a good beer. Professor Bruce Lewenstein was an ever-present force during my time at Cornell. I am grateful that from the first time we spoke on the phone when he told me that I had been accepted by Cornell, to the final touches of this dissertation, he has been a supporter of all areas of my life. I will always be indebted to him for his recognition of my need to prioritize both my family and my work, but most importantly, of his support when I needed to prioritize my family over my work.

My intellectual development during graduate school would not have been complete without the community that makes up the Department of Science & Technology Studies. I continue to value the Monday marathons of SSRGs and colloquia sponsored by our department. It was in these spaces that I began to make sense of our field and how I might contribute to it. In particular, Professors Steve Hilgartner, Trevor Pinch, Sara Pritchard, Christine Leuenberger, Kathleen Vogel, Phoebe Sengers, and Judith Reppy, as well as countless visiting scholars, served as phenomenal examples of the possible scholar and teacher I might one day become. In addition, I would have long ago lost my way if not for the patience, diligence, and knowledge of Stacey Stone and Deb Van Galder. From the first time I stumbled into their office they never stopped knowing all the answers to my questions.

In addition, Keith Hjortshoj's quiet insightfulness ensured that, during a time when with only a little push in the other direction I very well may have left graduate school, that I re-remembered why I came and found the confidence to continue forward. Finally, Kris Corda of the Big Red Barn became my boss, friend, and stand-in mom during my time in Ithaca. She was the first person I told about my job offer and the last I said good-bye to upon departing Cornell. Her personality and approach to life are infectious and I hope that I can one day be as generous and loving a person as I suspect she always has been.

I want to express my gratitude and appreciation to my informants for their generosity in giving me time and attention. In particular, the work of this dissertation would not have been possible without the candid conversation of Rae Ostman, Catherine McCarthy, Greta Zenner-Petersen, Paul Martin, Larry Bell, Troy Livingston, Brad Herring, Margaret Glass, and countless informal science educators from throughout the United States.

Only through the financial support of my work and life during this time was this dissertation made possible. In particular, the National Science Foundation has supported me in a number of ways. Beginning as an undergraduate at the University of South Carolina, I was awarded funds as part of the USC NanoCenter's Nanoscale Interdisciplinary Research Team (NIRT) grant. At Cornell, I was funded by a NSF Emerging Technologies Fellowship as well as a NSF Dissertation Improvement Grant (Award No. 0924379). Also, Michael Lynch's NSF Scholar's Award, titled "Visualization at the Nanoscale: The Uses of Images in the Production and Promotion of Nanoscience and Nanotechnology" (Award Number 0822757) supported my research efforts during this time. The Cornell Graduate School generously provided more than five years of funding, including the Sage Fellowship, numerous teaching and research assistantships, and multiple conference and research travel grants. In addition, the Graduate School put into place a paid parental accommodation policy, giving me paid time away after the birth of my daughter, as well as a Childcare Grant, which enabled my ability to manage the high costs of childcare on a graduate school budget. Kris Corda of the Big Red Barn made it possible for both me and my husband to work flexible hours, often bringing our daughter to work, throughout our time at Cornell. Lastly, my colleagues at Arizona State University and the Center for Nanotechnology in Society, especially David Guston and Cynthia Selin, have made putting together the final details of this dissertation possible through their financial and intellectual support.

The graduate students at Cornell continue to be a source of expertise, encouragement, and humor, which have sustained me as I have moved from stage to stage (and place to place) in this process. Beginning during my first years as a graduate student the enthusiasm, experience, and guidance of Jofish Kaye, Janet Vertesi, Lisa Onaga, Carin Berkowitz, Manjari Mahajan, Nicole Nelson, Anna Geltzer, and Katie Proctor were instrumental to my development. I continue to feel very lucky to have benefited from sharing the physical and intellectual space of Tyson Vaughn, Ling-Fei Lin, Anto Mohsin, Darla Thompson, Robb Schombs, Kasia Tolwinski, Alexis Walker, Victor Marquez, and Angie Boyce. Many other Cornell and Ithaca friends provided warmth and friendship to get us through the long winters of Ithaca. In particular, our time in Ithaca would not have been the same without the good food and even better conversation of Henry Berlin and Fernanda Negrete, Jum Warritay, Zac Zimmer, Zach Gooch, Yoon Oh, Scott Golder, Megan Halpern, and Max Evjen.

We continue to be grateful for Emma Zuroski who not only volunteered her time, for free, to patiently watch over our less than patient infant while we worked, but became a good friend as well.

And finally, I will always be thankful for the luck of entering graduate school with Hannah Rogers and Honghong Tinn. In many ways, Hannah and Honghong shaped my intellectual and personal development during this time more than any two other people. They assuaged my isolation as I sat through my first graduate seminar in S&TS and realized I knew nothing about a field in which I was going to try to receive a degree, and we were together during our first teaching experiences, which was really yet another learning experience about what WE had yet to learn. They supported, hugged, laughed with, and counseled me as I tried to figure out how to manage from afar the complexities of a dying parent and the obligations of a PhD. Even as our physical distance has increased, they have been unflagging partners during my final years of graduate school, the actual writing of this dissertation, the acceptance our first publications, the multiple years of trying to figure out how to present ourselves as scholars to show that we deserved employment, the moves across the country and sometimes across the world (and back again), and the process and challenge of learning to balance all of these changes with our personal lives and the priorities of husbands, partners, fiancés, and new babies. I look forward to what awaits us.

Without my close friends and family, finishing this dissertation would not have been possible. Since I was fourteen, Leslie P. Lance has been the kind of friend that most people only get to read about in novels. I continue to be grateful for the constant generosity and love that she and her family—Mimi, Steve, Lyle, Lauren, Jonathon, Ian, and Asher-- have bestowed upon me and mine. In spite of the distance and complexities of modern life, they have played an important part of every major event of my recent life and most of the less major ones as well. During this time, I am grateful for the opportunity to call what was once another family my own. Andre, Linda, Christina, Isaac, Lucas, Dorian, Gustaaf and Rupa sustained me and mine with provoking conversation, excellent drink, and even better food.

My father has lived with, through, and around every challenge and each success that this dissertation represents. I am grateful for his unwavering trust and continued support, especially during those moments when I had so much trouble explaining what it was that I was actually doing and why it might be important.

My sister, Kristen, and her family, Kit, Kallen, and Kolden have served as a model for the possibilities available to a person if she remembers what is most important and prioritizes it above all else. I continue to be grateful for their unending generosity and hope that they know it did not go unnoticed.

My mother was not here to see this part of my life move on to the next, but nevertheless, without her none of it would have been possible. She was my biggest fan and greatest critique, having made all of these things possible.

It is Antonio and Josephine whom I am most inadequately equipped to thank but to whom I owe the most. I know in the writing of these few acknowledgement pages that I have fallen short in fully expressing my appreciation to others, but to them, I will always be unable to convey the value of their presence in my life. For Josephine, I hope that the way I lived my life during the completion of this dissertation and my degree will serve as a helpful example in your own. In many ways, it was your arrival into this world that cemented my resolve to complete this project. And Antonio, because of you I will now always possess the gift of living continually

somewhere between our imaginations and reality. It is somewhere in that space from which this dissertation emerged. I am grateful for the words of another to help me explain.

> *Yet they had met,*
> *Friend and dear friend and a planet's encouragement.*
> *The barbarous strength within her would never fail.*
> *….*
> *Never forgetting him that kept coming constantly so near.*
> *WALLACE STEVENS*

Kathryn de Ridder-Vignone
Tempe, AZ
December 2012

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LIST OF ABBREVIATIONS

AISL	Advancing Informal STEM Learning
ASTC	Association of Science-Technology Centers
CAISE	Center for Advancement of Informal Science Education
CNS	Center for Nanotechnology in Society
DEA	Diversity Equity and Access
GMO	Genetically Modified Organisms
IPSE	Interns in Public Science Education
ISE	Informal Science Education
MOS	Museum of Science-Boston
MRS	Materials Research Society
NCMLS	North Carolina Museum of Life and Science
NISE	Nanoscale Informal Science Education
NSEE	Nanoscale Science and Engineering Education
NSF	National Science Foundation
OMSI	Oregon Museum of Science and Industry
SEI	Societal and Ethical Implications
STS (S&TS)	Science & Technology Studies
PE	Public Engagement
PUS	Public Understanding of Science
PUST	Public Understanding of Science & Technology
SMM	Science Museum of Minnesota
USC	University of South Carolina

CHAPTER 1

INTRODUCTION

In 1917 Marcel Duchamp sat on the board of the Society of Independent Artists. Unbeknownst to the board, he submitted *Fountain* to their 1917 exhibition. Although all works of art submitted were supposed to be included in the exhibition if the artist paid the submission fee, the Society of Independent Artists decided not to make the piece visible during the exhibition. Duchamp later resigned from the board in protest.

In response, the New York Dadaists took an active part in documenting and publicly criticizing the Society's actions. That same year Alfred Stieglitz published a photograph of the piece along with a letter and writings by other important artists and patrons in the second issue of *The Blind Man.* In an anonymous editorial included in *The Blind Man,* the author argues that whether or not the urinal itself was made by the artist is irrelevant. The editorial states:

> Whether Mr Mutt[1] with his own hands made the fountain or not has no importance. He CHOSE it. He took an ordinary article of life, placed it so that its useful significance disappeared under the new title and point of view – created a new thought for that object (capitals in the original).[2]

Should *Fountain* have been included in the exhibition and recognized as art? What did the board think was at stake, what would be lost or validated, if this urinal

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[1] *Fountain* had been signed by Mutt though the meaning of the signature was always ambiguous.
[2] Anonymous, "The Richard Mutt Case," *Blindman* no. 2 (n.d.): 5, accessed November 2, 2012.

was included as an example of new art knowledge? Almost 100 years later, *Fountain* is still thought of as one of the most influential artworks of the 20th century. It would seem that if art is a way of knowing the world, then *Fountain* represents new knowledge about that world. And yet the world still argues about who has the power and authority to create new knowledge.

The controversy and legacy of Duchamp's ready-mades underlie a significant point of this dissertation: How is new knowledge created? Can one be a knowledge creator even if he/she does not materially make, as with the urinal, or in this study, as with laboratory data, the objects which are the focus of the new knowledge? What is lost if our criteria for knowledge creation require that only those who create the objects, create the knowledge?

The answers to these questions are no less complicated for scientific knowledge making than for artistic. In a laboratory, how do we determine who actually creates scientific knowledge? Is it the Principal Investigator who directs the research, lends her name to publications, and develops grants to maintain the work of the laboratory and the individuals the laboratory relies upon? Or are the graduate students, postdoctoral researchers, laboratory technicians, and many other individuals who perform the experiments and document the results the only individuals who create knowledge in a laboratory? Perhaps, in fact, the only knowledge creators in a laboratory are the computers, microscopes, and dozens of other technologies and technological processes which process, synthesize, and make evident the data which as been gathered by those aforementioned people?

Another way of answering these questions may require us to look at "Science" holistically. For science and scientists to continue creating and testing theories about the relationships among observable phenomenon, they are dependent upon, at least, three major factors not determined by what professional scientists do in a laboratory, at conferences, in publications, and elsewhere.

1. There must be new scientists. Without individuals interested and actively pursuing the education and professionalization that is required to do science as a vocation, no new scientific knowledge will be created.
2. "Science" can only operate within societies able to support it. In other words, when technoscience is used in such a way as to degrade the society in which science operates, new scientific knowledge is not created. War or what have become today's "natural disasters" are probably the most obvious examples of such degradations.
3. Hand-in-hand with the maintenance of infrastructures that enable scientific knowledge creation, is the need for political goodwill. In other words, if publics (be they individuals, governments, or private businesses) and their representatives are not convinced of the utility and value of scientific pursuits, the money to support those pursuits will be difficult to acquire.

Therefore, which circumstances and acts truly create scientific knowledge? It might seem that if all of these circumstances are not necessary for knowledge creation, then perhaps only the nonhuman actants of the laboratory truly create new knowledge? The same logical fallacy which would deny the agency of all of the individuals, no matter their status, *but* which validates the technologies, practices, and methods of the laboratory to create scientific knowledge, also denies the authority of policymakers, social scientists, educators, and even publics to create scientific knowledge. This dissertation is about those people.

This dissertation argues that informal science educators do more than regurgitate, reformulate, or reorganize scientific knowledge – they create it. This research documents the pathways through which science is democratized and legitimized. My definition of "knowledge creation" relies on the assumption that informal science educators, given their sensitivity to the possibility of "devaluing" scientific knowledge, are well-positioned to take into account "professional science" and place it into context with other forms of knowledge, thereby creating a more enriched definition of science than the scientific community could do alone. The particular area of science on which I focus is "emerging technologies."

So-called "non-traditional knowledge making" or the scientific legitimacy of "local knowledge" has already been demonstrated. Brian Wynne's Cumbrian sheep farmers, for example, serve as an important example of the value and difficulties of knowledge legitimization by groups not traditionally seen as holding scientific authority.[3] Similarly, the Love Canal Homeowners' Association's research on the health effects associated with the movement of toxic substances through underground waterways in its neighborhood was the only study that existed. The challenges associated with demonstrating the legitimacy of local knowledge are clear: The New

[3] Brian Wynne, "Misunderstood Misunderstanding: Social Identities and Public Uptake of Science," *Public Understanding of Science* 1, no. 3 (July 1, 1992): 304, 281.

York State Health Department, before even seeing the results of the Homeowners' study, dismissed the information as "information collected by housewives that is useless."[4] Yet these examples and others show that local knowledge can often be more complete and accurate than "conventional scientific standards"[5] and therefore deserves to be included in our definition of science and technology.

Descriptions of the making of scientific knowledge, even social constructivist approaches, that validate knowledge created inside a laboratory or other spaces of scientific research but disregard how that knowledge is defined, characterized, and negotiated in other scientific social spheres arbitrarily gives authority to the laboratory and its actors. But asking why and under what circumstances scientific knowledge stabilizes requires us to recognize that the epistemological status of scientific knowledge is established beyond the laboratory by educational institutions, media stories, museums, and the work of many kinds of science-related practitioners. In fact, the authenticity of laboratory science may depend entirely on its "popularization" and whether non-scientists are given the authority and power to take part in such action.[6]

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[4] Adeline Levine, *Love Canal : science, politics, and people* (Lexington, Mass.: Lexington Books, 1982), 93.

[5] Steven Epstein, *Impure science : AIDS, activism, and the politics of knowledge* (Berkeley: University of California Press, 1996); Sharon Macdonald, "Authorising Science: Public Understanding of Science in Museums," in *Misunderstanding Science?*, ed. Alan Irwin and Brian Wynne (Cambridge University Press, 1996), 152, http://dx.doi.org/10.1017/CBO9780511563737.

[6] S Hilgartner, "The Dominant View of Popularization: Conceptual Problems, Political Uses," *Social Studies of Science* 20, no. 3 (1990): 519–539; T. Shinn and Richard P. Whitley, *Expository Science: Forms and Functions of Popularisation* (Springer, 1985).

One particular set of practitioners are those who identify themselves as "informal science educators." This study examines informal science educators as knowledge-makers, even while many of these educators do not recognize their social position as such or even actively deny that they have such a function. I show how their own inability or unwillingness to view themselves as knowledge-makers has led them to take few strides towards demonstrating their ability, perhaps even their right, to be seen not only as authorities on science communication, but as necessary actors in the selection, categorization, and stabilization (read: creation) of scientific knowledge. Historically, before the work inside of science museums was defined as informal science education, such museums were already acknowledged as sites of knowledge production. For instance, Jan Golinski writes in *Making Natural Knowledge*, the museum

> is a setting in which natural knowledge is constructed in the very process of display itself, without that display making reference back to some anterior location or previous occasion of private experimental work. The museum presents what Markus calls "visible knowledge"; the things shown there are made known in the act of being displayed. Artifacts and natural objects displayed in museums have been gathered together from a variety of places, and they may be interpreted as signs of something else (for example, the world of nature) that is not viewed directly; but it is the act of showing that directly makes them known.[7]

Informal science educators perform these "act[s] of being displayed," but not necessarily through the collection and exhibition of material artifacts. Instead, their

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[7] Jan Golinski, *Making Natural Knowledge: Constructivism and the History of Science, with a New Preface* (University of Chicago Press, 2005), 95.

work reflects careful and deliberate selections of particular aspects of science and technology, demonstrated through a variety of means – in the case of this dissertation, art, table top exhibits, and deliberative democracy events. These "act[s] of showing" are exactly what makes the selections known. The act of telling a story about what to know, what to value and how to value it, creates knowledge.

Informal science educators do this, most obviously, through the materialization of exhibits and programs. However, the exhibits and programs are only the last stage of this knowledge-making. These exhibits and programs are the product of a cascade of planning documents, publications, instructional manuals, professional development workshops and meetings, evaluations, and professional presentations and conferences. They reflect the best methods of learning about science and technology for educators and visitors alike, propagating the ISE field's educational priorities, institutional allegiances, and professional values. Shaping more than their publics' basic knowledge of scientific phenomena, scientific methods, or scientific thinking, informal science educators' intellectual and material work shapes individuals' expectations *and knowledge* of science and technology.

The field of Informal Science Education (ISE) is made up of practitioners from a wide variety of institutions and locations.[8] Such sites include everything from libraries to museums, science centers to aquariums, nature centers to amateur bird-watching societies. What these locations share is an attention to "free-choice"

[8] Philip Bell et al., eds., *Learning Science in Informal Environments: People, Places, and Pursuits*, vol. Division of Behavioral and Social Sciences and Education, Board on Science Education Center for Education (Washington D.C.: National Academies Press, 2009).

learning and education for adults. Children are a huge contingent of individuals who participate at these sites, but adults are almost never excluded.[9] ISE has not completely determined the degree to which its imagined audience is made up of adults, but researchers have acknowledged the crucial role that ISE plays in the life-long science learning of adults and children in the United States.[10] Falk and Dierking argue that 95% of Americans' science education occurs in informal settings. Before age twelve, children in the United States perform better than their peers in other countries in science. Falk and Dierking attribute this phenomenon to American's more prolific access to and use of informal institutions of learning.[11] After age twelve, children in the United States no longer participate in ISE to the same degree. After university, these adults reacquaint themselves with informal learning experiences. The authors argue that this pattern may, in fact, be the reason for Americans' ability to "catch up" scientifically after lagging behind the world during high school and college.

Adult learners are a large part of my research, given their greater political, social, and financial autonomy. These aspects of civic life are important for understanding the role (adult) publics play in constructing emerging technologies and thereby democratizing science. Adults' and imagined adults' autonomy is important

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[9] John Bransford et al., *How people learn brain, mind, experience, and school* (Washington, D.C.: National Academy Press, 1999), http://site.ebrary.com/id/10041047. The majority of formal education is, of course secondary education. Even though university education affords a place for adults, the majority of their life-long learning experiences will occur outside a classroom.
[10] John H. Falk and Lynn D. Dierking, "The 95 Percent Solution," *American Scientist* 98, no. 6 (2010): 486, doi:10.1511/2010.87.486.
[11] Ibid.

to understanding how learning for these audiences is conceptualized and created by practitioners. Given the large impact ISE plays in the science education of both future adults and adults, this dissertation asks: What counts as ISE and what role does ISE play in defining a particular domain of science, emerging technologies, for the public? In addition, how might emerging technologies, particularly nanotechnologies, challenge traditional or historical ISE practices?

The Nanoscale Informal Science Education (NISE) Network began in 2005. It was the first large scale informal science education network of science museums and centers funded by the National Science Foundation. It was created specifically to create educational programming about nanotechnologies for the public. As discussed on the NISE Network's website,

> Advances in nanoscale science, engineering, and technology are revolutionizing medicine, computing, materials science, energy production, and manufacturing. Yet, to the general public, these advances can be invisible or difficult to understand. The NISE Network was created to engage the public in advances in nanoscale research, to capture the imagination of young people who may subsequently choose careers in nanoscale science or technology, and to foster new partnerships among research institutions and informal science centers.[12]

Knowledge creation is not explicitly included as a goal of this network. Nevertheless, much of my argument rests on the assertion that informal science educators serve as powerfully as scientists in defining emerging science and technology. The power of informal science educators to define science and

[12] "Welcome to the NISE Network | NISE Network," accessed September 10, 2012, http://www.nisenet.org/about.

technology is debated within science education, as well as within science policy. Educators and their authority are often considered subservient to scientific researchers and experts, especially in the institutions dominated by these professional groups' scientific norms (such as the NSF and some science museums). This subservient place within the world of scientific knowledge creation means that those who have the most expertise interacting with non-experts are not those given the most authority (or money) to do so. This dissertation explores how some social groups and not others are credited with creating scientific knowledge and why that is significant to the definition of emerging technologies and science education. In doing so, I will define what counts as technoscientific knowledge to demonstrate how a group can produce scientific knowledge, even when it does not acknowledge that production.

When I began my research on the NISE Network the legacy of Eric Drexler and his definition of nanotechnology had not waned, but Drexler's influence was also being swept from the short history of nanotechnology.[13] For example, in 2005, the University of South Carolina hosted an international conference called "Nanoethics," and extending an invitation to Eric Drexler occurred in the midst of heated debate. Organizers wondered whether his presence would delegitimize an institution (USC) in the midst of building its reputation as a leading authority on the ethical, social, and legal issues associated with nanotechnologies.

[13] Kaplan S and Radin J, "Bounding an emerging technology: Para-scientific media and the Drexler-Smalley debate about nanotechnology," *Social Studies of Science* 41, no. 4 (2011): 457–485.

Drexler and Nobel Laureate Richard Smalley had taken part in a public debate published in *Chemical and Engineering News* in 2003, with Smalley critiquing Drexler's definition of nanotechnology and its potential. By the time I began my research on the NISE Network in 2007, scholars studying biological nanosystems were silently incorporating the mechanical metaphors and images of Drexlerian visions.[14] Both the images and the vocabulary were shared, although no explicit mention was made of the rhetorical similarities of this research examining biology at the nanolevel to Drexlerian depictions of self-replicating "nanobots." By contrast, I was immediately aware of the *lack* of Drexler-like language and images in the stories and programming of the NISE Network. This struck me because of my interest in the role images and visualizations played in constructing the definition of nanotechnologies for publics.

Upon inquiring, I was told that the NISE Network deliberately chose to select out the legacy or existence of Drexler, rhetorically and visually, as a means of presenting nanotechnology as an uncontroversial, safe new technology. The Network believed that trying to present nanotechnologies as important due to their new and interesting capacities while also acknowledging the unpredictability of the unknown could potentially lead to a public backlash, much in the way of Europeans' response to GMOs.

David Ucko, the first NSF program officer to the NISE Network, said, informally, that the network was created deliberately to avoid such a backlash and

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[14] Ibid.

including Drexler in any story about nanotechnologies would endanger the NSF's efforts to promote nanotechnology.[15] This was the first example I learned about in the NISE Network of selecting out (gray goo and self-replication in this case) in an attempt to satisfy NSF priorities and to stay within the confines of what informal science educators in the NISE Network believed to be their purview: presenting the uncontroversial "facts." This dissertation demonstrates how in the selection of these "facts" educators create technoscientific knowledge.

Science museums have had a long history of cultural significance in society. There are many histories which assess how, when, and why these institutions have changed.[16] This dissertation, which focuses not only on science museums as

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[15] Dave Ucko, "Interview by Author with NSF Program Officer and ISE Leader" oral, September 2009.

[16] Gail Anderson, *Reinventing the Museum, Historical and Contemporary Perspectives on the Paradigm Shift* (AltaMira Press, 2004); Susan M Pearce, *Museums, objects, and collections : a cultural study* (Washington, D.C.: Smithsonian Institution Press, 1993); Stephen E Weil, *A cabinet of curiosities : inquiries into museums and their prospects* (Washington: Smithsonian Institution Press, 1995); Tony Bennett, *The birth of the museum : history, theory, politics* (London; New York: Routledge, 1995); Andrea Witcomb, *Re-imagining the Museum: Beyond the Mausoleum*, Museum Meanings (London ; New York: Routledge, 2003); Hilde Hein, *The Exploratorium : the Museum as Laboratory* (Washington: Smithsonian Institution Press, 1990); Eilean Hooper-Greenhill, *Museums and the shaping of knowledge* (London; New York: Routledge, 1992); Arthur Molella, "Exhibiting Science in Historical Context: The Case of 'Science in American Life'," *Museum Anthropology* 26, no. 1 (2003): 37–49; Steven Conn, *Museums and American Intellectual Life, 1876-1926* (Chicago: The University of Chicago Press, 1998); Ken Arnold, "Chapter 11: Birth and Breeding: Politics on Display at the Wellcome Institute for the History of Medicine," in *The Politics of Display: Museums, Science, Culture*, ed. Sharon Macdonald, 1st ed. (Routledge, 1998), 183–196; Thomas F Gieryn, "Chapter 12: Balancing Acts: Science, Enola Gay and History Wars at the Smithsonian," in *The Politics of Display : Museums, Science, Culture*, ed. Sharon Macdonald (London New York: Routledge, 1998); Stella V Butler, *Science and technology museums* (Leicester

institutions, but on what is now called the field of informal science education, has had to take into account scholarly literature from the large variety of fields and disciplines which examine ISE. Some of these fields include museology, museum studies, visitor studies, history of science and technology, public understanding of science and technology, and science communication. All of these areas have spoken for and about the work of ISE, thus shaping the face of ISE today. This dissertation does not attempt to locate exactly which one of these groups has held the most authority over shaping the practices and priorities of ISE (mostly because these groups are neither stable nor unambiguous in their influence). I do, however, acknowledge the authority of each in an attempt to portray how the interaction of these different groups contributes to defining the field and helps us to understand two important questions: What counts as the right kind of informal science education today, and who determines this?

In part, the answer to this question is found through the combination of two primary aspects of ISE: learning and communication theories (the use of the deficit model, for instance) applied to specific content (emerging or contemporary science and technology, for example). The following section will outline the dominant communication models employed by ISE and then will try to look at the tensions

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[u.a.]: Leicester Univ. Press, 1992); Silvio A. Bedini, "The Evolution of Science Museums," *Technology and Culture* 6, no. 1 (Winter 1965): 1–29; Karen A. Rader and Victoria Cain, "From Natural History to Science: Display and the Transformation of American Museums of Science and Nature," *Museum and Society* 6, no. 2 (July 2008): 152–171.

associated with using these models to present contemporary or emerging technoscience.

These four models are the deficit and contextual model and the lay knowledge and public engagement model. The first two models focus primarily on the successful delivery of information to people usually from some part of the scientific community while the lay knowledge and public engagement models are thought of as dialogic or interactive models because they examine the relationship and interactions between publics and the scientific community. This dissertation is not going to go into depth explaining these models or their history, particularly because this has been done well elsewhere.[17] The following Table 1.1, however, is a brief synopsis primarily based on a paper given by B.V. Lewenstein "Models of Public Understanding: The Politics of Public Engagement."[18]

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[17] Bruce Lewenstein and Dominique Brossard, "A Critical Appraisal of Models of Public Understanding of Science: Using Practice to Inform Theory.," in *Communicating Science: New Agendas in Communication* (New York: Routledge, 2009), 11–39; Lewenstein, Bruce, "Models of Public Communication of Science and Technology," 2003, 1–11; Bruce Lewenstein, "Models of Public Understanding: The Politics of Public Engagement," in *ArtefaCToS*, vol. 3 (presented at the New views and challenges in science communication and the promotion of scientific culture, Universitat de València: Scribd, 2010), 13–29, http://www.scribd.com/doc/92477522/Models-of-Public-Understanding-Bruce-Lewenstein.

[18] Lewenstein, "Models of Public Understanding: The Politics of Public Engagement."

Table 1.1 Models of Public Communication

Model	Method/Communication Strategy	Goal	Critique	Where has it been employed?
Deficit	Increase scientific literacy or reduce the public's "presumed" deficit of scientific knowledge through the transmission of knowledge	More knowledgeable public	It's never been clear what "filling the deficit" will do though there's an underlying assumption that a more knowledgeable public will result in a public more supportive of science, creates a hierarchy which values those who "know" more also have more power, does not account for why knowing more scientific facts deems you more important politically	NSF and EU's science literacy surveys, U.S. secondary education science curricula, many ISE initiatives
Contextual	Provides social context of knowledge delivered	More knowledgeable public	Does not recognize why different audiences may have different needs, does not address the factors underlying these different needs	Museums and science centers
Lay Knowledge	Recognizes the existence of and gives authority to local knowledge	Transfer authority, especially scientific authority to nonexperts	Difficult to employ as a communication strategy. Also, even though local knowledge is collective community knowledge (not just the anecdotal knowledge of one	Wynne's study of the Cumbrian sheep farmers, Citizen science projects, science museum's

			person), scientists are wary of it if accepting it means giving up some of their political and technical authority	(like SMM) community "talking" groups
Public Engagement	Strategies to bring publics and their knowledge and skills into (formal) policy making	More citizen involvement in technoscientific policy decisions, turning over scientific authority to nonexperts	Unclear as to whether these exercises actually contribute to real changes in policy outcomes or if they are simply meant to publicly validate decisions made by technocratic experts by standing in as "proof" that citizens were involved, even though no real authority or power was ever handed over to them, activities often only involve small groups of citizens	Consensus conferences

In the last twenty years, science communication scholars have begun to discuss the importance and challenges of presenting "contemporary science," also known as "science in the making," or "emerging or current science and technology" in museum settings.[19] Many of the major tensions, themes, and foci of the NISE Network

[19] David Chittenden, Graham Farmelo, and Bruce V Lewenstein, *Creating Connections : museums and the public understanding of current research* (Walnut Creek, CA: AltaMira Press, 2004); John Durant, "Introduction," in *Museums and the Public Understanding of Science* (London: Science Museum in association with the Committee on the Public Understanding of Science, 1992), 7–14; S Shapin, "Why the

cooperative agreement with the National Science Foundation had their roots in previous conferences and discussions in the science communication and informal science education fields. Many of the tensions and challenges confronted by the actors in this study were part of a larger discussion in ISE as a whole that began in the early 2000s.

Steven Shapin, in the first issue of the journal *Public Understanding of Science,* argued that if the public is going to continue supporting scientists and their work, then their workplaces and the messiness within them, what he terms "science-in-the making," must become part of the public's understanding of science.[20] John Durant argued in his edited volume about the role of museums in the public understanding of science that one of the failings of both science centers and science museums is the "presentation of science as a fixed body of knowledge and the presentation of science divorced from its immediate social context."[21] Durant gave recommendations for both science museums and centers on the best way to avoid these two tendencies.

Graham Farmelo and Janet Carding organized an edited volume titled *Here and Now* based on a conference of the same name held at the Science Museum, London, in November of 1996. Their collection of essays examines what is at stake as museums and science centers "struggle to cope with the welter of controversy, complexity, and

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Public Ought to Understand Science-in-the-making," *Public Understanding of Science* 1, no. 1 (January 1, 1992): 27–30, doi:NO_DOI.

[20] Shapin, "Why the Public Ought to Understand Science-in-the-making."

[21] Durant, "Introduction," 10.

uncertainty at [the] frontiers" of contemporary science.[22] The volume focuses primarily on whether institutions should "even try to keep up with science and technology" and "the slippery meaning of 'contemporary.'"[23] The conclusion and recommendation: collaboration.

Farmelo and Carding, as well as many of the volume's contributors, do not see any way that museum professionals, with all the variances in their institutions' abilities, priorities, experiences, and resources, can possibly begin to manage the added complexities of focusing on and presenting contemporary science, unless those institutions forge professional partnerships with other institutions both scientific and educational. This type of collaboration was a major charge of the NSF for the NISE Network. "The NISE Network was created to … foster new partnerships among research institutions and informal science centers," according to the Network's website.[24] In a later book called *Creating Connections: Museums and the Public Understanding of Current Research,* Farmelo said that "if museums really want to cover new developments in scientific research, they will have to forswear their traditional insularity and conservatism—an undertaking often claimed but more often honored in the breach than the observance."[25] The traditions of insularity and

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[22] Graham Farmelo and Science Museum., *Here and Now : Contemporary Science and Technology in Museums and Science Centres : Proceedings of a Conference Held at the Science Museum, London, 21-23 November 1996* (London: Science Museum, 1997), 15.
[23] Farmelo and Science Museum., *Here and Now*.
[24] "Welcome to the NISE Network | NISE Network."
[25] Chittenden, Farmelo, and Lewenstein, *Creating connections*, 6.

conservatism to which Farmelo refers have been documented in many histories of museums.[26]

Though perhaps not a completely fair critique since museums, particularly science museums, have often been on the frontier of thought and policies associated with more democratic access to education and knowledge, Farmelo's comments accurately reflect one of the largest challenges of developing the NISE Network. Contemporary museums and science centers typically do not collaborate to develop educational products meant to be distributed and presented to publics at a variety of sites, what the NISE Network refers to as "deliverables." Part of museums' and science centers' incomes originate from renting or selling exhibitions or other intellectual property, which discourages collaborating with other institutions to distribute such intellectual property free of charge.

Creating Connections was also an edited collection in response to another conference, sponsored by the NSF and held at the Science Museum of Minnesota in 2002. This collection presents the "public understanding of current research" (often referred to as PUR) and its nascent role in museums. The authors argue that PUR's "aims and terms of discourse are not yet clear" nor yet had they been agreed upon by its practitioners. Having said this, the parameters of the debates within this inchoate field were visible themes of concern for the practitioners in my study in the years that

[26] Bennett, *The birth of the museum*; Eilean Hooper-Greenhill, *Museum, media, message* (London; New York: Routledge, 1999); Hooper-Greenhill, *Museums and the shaping of knowledge*; Farmelo and Science Museum., *Here and Now*; Weil, *A cabinet of curiosities*; Ken Arnold, *Cabinets for the curious : looking back at early English museums* (Aldershot, England; Burlington, VT: Ashgate, 2006).

followed that conference. In particular, the following questions posed by the editors of *Creating Connections* outline the parameters of the debates surrounding PUR in ISE at large, which seem to have served as a programmatic outline for the NISE Network:

1. What should audiences know about current research?
2. How much effort should be put into providing information to visitors about the institutional and political forces that shape science?
3. How should the public engage with researchers?
4. What role can/should museums play in the "public consultation of contemporary science issues?"
5. What are appropriate and realistic outcomes for PUR efforts in museums, and what are the implications of these decisions on [evaluation and] assessment?
6. What is the most beneficial way for institutions to gain from professional collaborations?
7. What role does PUR play in ensuring the future relevance of science centers and museums to adult and juvenile audiences alike?[27]

These questions were commonly asked by the NISE Network educators and seemed to guide the priorities of the Network, at least in the first five years.

In many ways, the aforementioned conferences and their associated publications, along with the founding of the Center for Advancement of Informal Science Education (CAISE) by the NSF and the publication of the National Academies-organized (and NSF-funded) study, *Learning Science in Informal*

[27] Chittenden, Farmelo, and Lewenstein, *Creating connections*, 11.

Environments,[28] reflect the radical changes taking place in the field of informal science education in the early 2000s and how those changes were (and are) being negotiated. The 2004 volume pointed out that the field was ready, interested, and willing to attend to these issues of presenting current scientific research in museums, just before the NISE Network cooperative agreement began; however, it was not clear if the scientific community, mostly in the form of the NSF, was willing or able to support this agenda. Many of the contributors to the volume were involved in the organization and management of the NISE Network, such as Rob Semper, Dave Ucko, Larry Bell, Carol Lynn Alpert, Dave Chittenden, and Bruce Lewenstein.

In many ways, the choice of nanotechnology as the focus of that future funding was merely opportune. Dave Ucko, a leader in the ISE field and the NSF program officer for the NISE Network, told me that choosing nanotechnology as the subject was a way of enrolling the necessary resources outside of the ISE community into a project relying on collaboration among science museums and science researchers and attending to the issues involved in presenting current or emerging science and technology.[29] What terms were necessary to gain the funding to support such a

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[28] Bell et al., *Learning Science in Informal Environments: People, Places, and Pursuits*.

[29] Currently, David Ucko is president of Museums + LLC. From his company's website, Museums + *more* LLC: "Prior to this position he served as the first Executive Director for a new National Academy of Sciences museum. In this position, Ucko established its direction as "wholesaler" of the best research underlying controversial science-based issues. He also served as the founding President of Science City at Union Station where he spearheaded the decade-long development of this educational attraction, linchpin for the transformation of Kansas City's historic landmark into a $250+ million mixed-use urban entertainment center. In Kansas City he pioneered the approach "recreational learning". While serving as Kansas City

project? Only one: Nanotechnology as the content area. In the wake of Europeans' response to GMOs, nanotechnology could simultaneously satisfy the ISE community leaders' interest in presenting a "current or emerging science" using collaboration and the NSF's interest in allaying any possible long term negative reaction to their scientific research agenda.

The questions that framed the debates of the actors in my study are also one way to acknowledge what other leaders in the ISE field such as Eric Jolly, the president of the Science Museum of Minnesota (SMM), or Lesley Lewis, the president of the Association of Science-Technology Centers (ASTC), were promoting during the same period: that ISE should play a meaningful role in society. These leader-practitioners believe that science museums should adapt and adjust to ensure their place in and impact on culture. The concerted interest by ISE in the late 2000s in

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Museum President, Ucko created the Science City concept of engaging visitors in learning adventures by combining hands-on discovery from science centers with immersive environments from theme parks and role-playing characters from theater." As Vice President for Chicago's Museum of Science and Industry and Deputy Director for the California Museum of Science and Industry (now California Science Center), Ucko *established new interactive exhibit directions* such as "My Daughter, the Scientist," "Technology: Chance or Choice?," "Everyday Chemistry," "Health Works," and many others. (From Museums+ LLC's website)."

During an informal conversation with Dave Ucko, he told me that from his perspective at least, the "nanotechnology" part of the grant wasn't really the most important aspect. Focusing on nanotechnology was a way to enlist those at NSF who may not have been concerned with the abilities of museums or ISE to attend to current scientific research, but who were greatly concerned with the public response or possible backlash to an emerging science that was not completely understood. Many members of the ISE community, of which Ucko is a part (he served as the program officer in charge of cooperative agreement with NSF), were essentially waiting around for the impetus (resources) to commit their institutions to collaborate and create programming focused on current science.

presenting current science and technology is proof of these practitioners' understanding that their social position is not a given. ISE must constantly negotiate with the political and bureaucratic structures of which their science museums are a part in order to decide what role they will play in defining science and technology in society. This dissertation, therefore, pays attention to how the relationship between policy makers, educators, visitors, and scientists shapes museum practices and goals to create public, technoscientific knowledge,[30] particularly about emerging technologies.

Eric Jolly served as a plenary speaker at the 2009 NISE Network Annual Meeting. Chapter 4 will discuss in more detail some of the attendees' reactions to his vision of ISE. However, the Sept/Oct 2008 issue of *ASTC Dimensions* (the ASTC newsletter) summarizes some of Jolly's most recent focus: making the science museum a site of social change where an emphasis is placed on "the interaction of science and societal concerns" to benefit local communities through engaged dialogue. In that issue, Robert Garfinkle the leader of the "Science and Social Change Program" at SMM, wrote:

> Under the direction of our president, Eric Jolly, SMM has launched the Science and Social Change Program to continue this work. We use the term "social change," which the International Council of Museums defines as "exploring issues with communities to contribute to their development," to advocate for strong collaboration between institution and community. We believe such collaboration is essential if a museum is to sustain a truly significant role in its community. We are now

[30] For the purposes of my study "public knowledge" refers to any knowledge that has been codified beyond the laboratory and has begun its move toward "popularization." This could include anything from scientific publications to newspapers, television, and museum exhibitions and their associated design plans and evaluations.

> exploring new projects that emphasize the intersection of science and societal concerns and engage the public in dialogue.[31]

In 2009, the CEO of the Ontario Science Center, Lesley Lewis, served as president of ASTC and as chair of the fifth Science Center World Congress. During a plenary talk at ASTC's annual meeting, she reemphasized ASTC's "Strategic New Direction," which is also summarized in the September/October 2008 issue of *Dimensions* in an article titled "The Road Ahead: ASTC's New Strategic Direction." Lewis wrote that "the main new ASTC strategy will be to address critical science and society issues proactively, in order to expand our reach, relevance, impact, and sustainability."[32] She said that ASTC's new focus on "critical science and society issues" had already been a priority of many of its members. The insistence of Lewis and Jolly on placing "science and society issues" as a top priority is significant because traditionally science museums and centers purposely avoided topics they considered ambiguous or political. In addition, the institutions of SMM and Ontario historically have an enormous amount of authority within the field based on their experience as leaders in exhibition design (SMM) and the implementation of new learning strategies (Ontario). Going back to Farmelo's definition of "conservative," in many ways ISE practitioners display this conservatism through their insistence on unambiguous portrayals of science and technology. Even institutions with the greatest authority, such as the Smithsonian, have dedicated themselves to a presentation of

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[31] Robert Garfinkle, "RACE: Fostering Community Conversations for Social Change," *Dimensions* no. Sept/Oct (2008): 7.
[32] Lesley Lewis, "The Road Ahead: ASTC's New Strategic Direction," *ASTC Dimensions* no. September/October (2008): 3.

science and technology that erases of much of its controversy, politics, or ambiguity, precisely those characteristics which define the social.[33]

ISE institutions serve as sites where educational leaders and practitioners interact with each other and their publics to define the relationship between democracy, science, society and the museum. In many ways, the future of ISE institutions will be determined by what role the institutions decide to play and how effectively leaders and practitioners manage to meet, predict, or define the changing priorities of these constituents.[34] As my dissertation will argue, many of the leaders like Lewis and Jolly have already begun promoting what they believe the future of ISE holds for educators and ISE as a whole. Two of the most important questions about the future of informal science education institutions are directly related to the priorities of these ISE leaders, namely: Can and should ISE intervene in the politics of science? What role does ISE play in defining public education about emerging technologies?

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[33] Arthur Molella, "Exhibiting Science in Historical Context: The Case of 'Science in American Life'," *Museum Anthropology* 26, no. 1 (2003): 37–49; A Molella, "Science in American Life, National Identity, and the Science Wars: A Curator's View," *CURATOR* 42 (1999): 108–116; Thomas F Gieryn, "Chapter 12: Balancing Acts: Science, Enola Gay and History Wars at the Smithsonian," in *The Politics of Display : Museums, Science, Culture*, ed. Sharon Macdonald (London; New York: Routledge, 1998).

[34] Peter Vergo, *The New Museology* (London: Reaktion Books, 1989); Hooper-Greenhill, *Museum, media, message*; Witcomb, *Re-imagining the Museum*. Vergo's edited volume was one of the first to recognize the need to assess how museums have established, developed, and tried to continue maintaining their educational role in light of social and political pressures. In particular, "museology" seeks to uncover the reasons attributed to the growth and success of museums by documenting a wide-range of factors including visitor response to exhibitions, practitioner deliberations about the future of the institutions, and the changes in the functions of exhibits and programs.

The three primary themes of this dissertation – science educators as scientific knowledge creators, the definition of ISE, the role of nonexperts in defining emerging science and technology – illuminate how informal science educators have the authority and expertise to define both an emerging technoscientific field and the practices and priorities of informal science education. In my study, I pay particular attention to the historical legacies of informal science educators and the field of ISE to understand how an emerging technology might challenge the traditional practices and beliefs associated with museum exhibitions and programming. I focus on the role practices, ideologies, and power play in defining the meaning of education, the field of ISE, and nanotechnology.

The Case: The Nanoscale Informal Science Education Network

The Nanoscale Informal Science Education (NISE) Network began in 2005. As of 2012, the network was the first large-scale (20 million dollars over ten years) cooperative agreement with NSF to create a network of informal science educational institutions which would collaborate to create educational deliverables distributed to science museums and centers throughout the United States. For this dissertation, I focused on the design, creation, and possible distribution of the network's three major educational modules of its first five years: ArtNano, NanoDays and NanoForums. Each of these case studies allows me examine in detail the questions mentioned above.

All three of my case studies reveal the efforts of artists, practitioners, and ISE leaders to expand the definitions of informal science education focused on emerging technologies and to demand the acceptance of the knowledge and practices of social groups not normally considered valid generators of scientific knowledge. In particular, this study focuses on how and why the knowledge production of some social groups is valued more than the knowledge of others in science education efforts by both educators and scientists alike.

The NISE Network and its leaders' priorities reflect many of the tensions within the ISE field at large. In particular, the field has not yet determined whether it can accept responsibility for presenting its own arguments for the relationship between science and society. If ISE educators, like scholars in the humanities, make arguments or deliver knowledge about science's place in society that shape and determine science's place in society, do they lose some of their cultural authority as presenters of "neutral" information? Do ISE institutions depend too much on the financial and public support of third-party constituents to weather those social groups' staunch disagreement with a museum's choice of presentation? How much does it matter that museums contribute to the stabilization of knowledge by their choice of displays, as opposed to presenting that knowledge only when it seems certain to other important social groups, given that knowledge about nanotechnologies has not stabilized? The answers to all of these questions have challenged the field's traditional practices. Some practitioners might argue that in fact the ISE field has determined a directional response to these questions. However, Chapter 2 points out that the field has in fact merely avoided confronting the content areas that make obvious its lack of consensus on some approaches (art practice, for instance) as valid science educational methods. The three substantive case studies look at the role art practices play in science learning (Ch. 2), the development and distribution of an educational module focused on the chemical and physical characteristics of nanoscience (Ch. 3), and the reception and staging of deliberative dialogue events or forums (Ch. 4).

Chapter 2, "ArtNano: Art, Artists, and the Wrong Kind of Science Education," examines the differences between scientists' and artists' authority to create science education experiences. This chapter makes evident that there is little consensus in ISE on whether art practices can serve informal science educational goals. In particular, given the field's interest in a particular type of evaluation (essentially, quantifiable results) and NSF's insistence upon this evaluation as a required component of the NISE Network agreement, only informal education programming that could be easily assessed through this type of evaluation was permitted to count as successful programming. In addition, although there has been some interest in the use of visual techniques to present complicated, invisible science within the NISE Network, priority was given to deliverables whose educational goals were easily quantifiable. According to the NSF and the ISE field, quantifiable learning goals proved that the deliverable was a valid educational experience. This chapter demonstrates how any experience whose effect was not easily quantifiable challenged this assumption and was therefore not taken up and distributed by the NISE Network.

The open-endedness of art methods and artist-educator practitioner approaches parallel the undetermined nature of nanotechnologies in society. However, in Chapter 2, I demonstrate that without leaders in the field or within the NISE Network who were willing to provide external pressure to prioritize the inclusion of art methods in the science programming, the use of art methods in science programming in the field as a whole gained no significant momentum. From time to time, specific institutions were able to put together the resources to create art/science educational programming, but this chapter demonstrates that without tapping into larger, more powerful social movements within the field of ISE, art practice remained a low priority in informal science education as a whole.

In Chapter 3, "Nanodays: Table-Top Exhibits and the Tension between Promotion and Education," I compare the power of the NSF to define the "best" science education with the power of informal science educators to deliver that education. The format and use of table-top exhibits are familiar to the field of ISE and, therefore, were easily designed and openly received. However, the format, and the associated expectations of the type of content delivered through that format, limits the kind of learning goals that could be achieved. This chapter argues that the world of ISE is still heavily dominated by individuals who adhere to an outmoded definition of science. Both in the NSF and in the ISE field at large, practitioners' insistence on viewing science as a stabilized, unequivocal body of knowledge and practices limits the type of science education practice that is possible.

Chapter 3 shows how organizations like the NSF play a powerful role in shaping what counts as the right kind of ISE through their massive funding, which is not available anywhere else. This chapter shows that it is not altogether clear how much autonomy educators have to actually develop new research and practices for the field when their resources are attached to so many strings. This chapter does not argue that the NISE Network should have been given *carte blanche,* but it does show how the NSF played a significant role in determining the kind of programming the NISE

Network would pursue, thereby shaping the nanotechnology-associated educational deliverables for the field as a whole.

This chapter also makes evident some important ideological contrasts among the practitioners who are defining the field. The people most directly involved with designing NanoDays represent a large contingency of practitioners, who have taken the lead in developing innovative educational practices for ISE, but who are not committed to pursuing the role their institutions might play in the politics of science. (Their perspective stands in contrast to the practitioners in Chapter 4, who address the role of ISE in the politics of science directly). For this group of practitioners who designed NanoDays, museums have a responsibility to teach visitors about the basics of the science, the chemical and physical characteristics of materials observed at the level of nanometers. Given that nanotechnologies have unique characteristics, the practitioners are dedicated to tackling the challenge of figuring out inventive and interesting ways to teach their publics about these characteristics.

These educators are particularly dedicated to instilling in ISE the expectation that all members of society should have access to this newly emerging science. They are leaders in promoting diversity among the visitors, especially in local, minority communities, and creating and distributing programming accessible to individuals with disabilities. For this group of practitioners, ISE is supposed to find a balance between education and entertainment. They are heavily focused on visitor needs and wants, particularly those of children and families. This group of practitioners within ISE essentially argues for the greater inclusion of certain visitors in ISE experiences while simultaneously supporting the exclusion of specific voices within the educational modules themselves. For example, they are less concerned with defining or acknowledging any long term political or social effects of the experiences they create than with ensuring valuable science educational experience that is also fun and exciting.

In Chapter 4, "NanoForums: The Role of ISE in the Politics of Science," I try to understand how informal science educators attend to the needs of technology-attentive and -inattentive audiences and promote learning experiences for adults specifically focused on dialogue and deliberation about emerging technologies. The NISE Network designers of NanoForums (a type of deliberative assessment of nanotechnology) were all individuals interested in redefining and changing the role science museums play in a democratic society. For them, the right kind of science education is that which focuses on the power that all citizens have to participate in and shape the outcomes of practices and policies associated with current science and technology. Even if the museum programs are not focused on particular policy endpoints, these educators believed that they should provide adult visitors with the critical thinking skills to better negotiate the complex information about science and technology with which they interact.

Chapter 4 further illuminates some of the differences among practitioners' priorities within ISE. The designers of NanoForums were a small group compared to some of the other working groups in the NISE Network, but in contrast to the designers of NanoDays, they directly tapped into the goals and priorities of the field's leaders like Eric Jolly and Leslie Lewis as a rhetorical strategy to argue that their work can and ought to be the new direction of informal science education (as justified by the mandates of the leaders). Having the support and resources of field leaders gave the designers of the NanoForums the leverage to convince educators who were not interested in the forums to commit to integrating them into their institutions' programs. Chapter 4 clarifies that, especially with the convergence of new deliberative dialogue programming models and an emerging technology topic, museums will not only be required to directly participate in the politics of science as representatives of particular viewpoints but also will begin taking a more deliberative role (as aquariums and zoos have done for conservation and sustainability), intervening in and promoting public responses to and knowledge about the crises, controversies, and complexities associated with emerging technologies.

Chapter 4 also demonstrates why deliberative dialogue activities are not universally accepted by science museums and centers as a type of programming worthy of their time or energy. I show that the field has not wholly convinced itself that programming for adults should be a priority, nor has it come to a consensus as to whether the museum space, its resources, and reputation should be used for science learning deliberatively focused on empowering adults to play a more active role in shaping science and technology in their communities. This illustrates the unresolved tensions in the field associated with the museum's role in creating learning experiences directly confronting science as a social process.

Because the majority of museum work focuses on science and technology which has stabilized, practitioners hesitate less to demonstrate the relationship of that sort of science to society, since to a great extent a consensus has already been reached about such relationships. In contrast, there is little consensus about the relationship between cutting-edge science and technology and contemporary society, and the museum's voice therefore plays a significant role in determining that consensus. Although the leaders of the Forums team, and other important figures in the field, are comfortable with this possible role for ISE, Chapters 3 and 4 demonstrate that many ISE professionals are not.

The Organization of the NISE Network

The NISE Network is led by the Network Executive Group, which is made up of the principal investigators who originated from the three core institutions: Museum of Science, Boston or MOS (Larry Bell and (originally) Carol Lynn Alpert); SMM (Paul Martin); and the Exploratorium (Rob Semper and (originally) Tom Rockwell). In the nine months leading up to submitting a proposal for the grant, these institutions decided to collaborate and submit one proposal as a group, as opposed to individually submitting proposals to the NSF. They counted approximately fourteen "core partners" in the grant, including Oregon Museum of Science and Industry or OMSI, Lawrence Hall, Ft.Worth Museum of Science and History, Houston Children's Museum, University of Wisconsin-Madison's Materials Research Science and Engineering Center or MRSEC, Materials Research Society or MRS, Sciencenter, New York Hall of Science, Franklin Institute, ASTC, and North Carolina Museum of Life and Science or NCMLS (see Figure 1.1).

Figure 1.1 NISE Net Core Partners

Being a core partner means that an institution receives funding from the NISE Network. The majority of these partners, plus a few others, made up the "Tier 1" group, which "develop[s] expertise at creating nano educational materials and building the network."[35] Tier 2, which was made up of approximately 100 institutions, was supposed to "develop expertise at presenting nano educational experiences for the public in ongoing activities." Tier 3, which ideally would contain over 300 institutions, would be "introduced to nanoeducation and presenting it occasionally." In addition, in order to organize the Tier 2 and 3 partners, the network created "Regional Hubs" with a liaison in charge of professional development, communication, and distribution to the members of Tier 2 or 3 in their region (see Figure 1.2).

[35] Larry Bell, "NISE Net Year 4 Explanation," March 8, 2009.

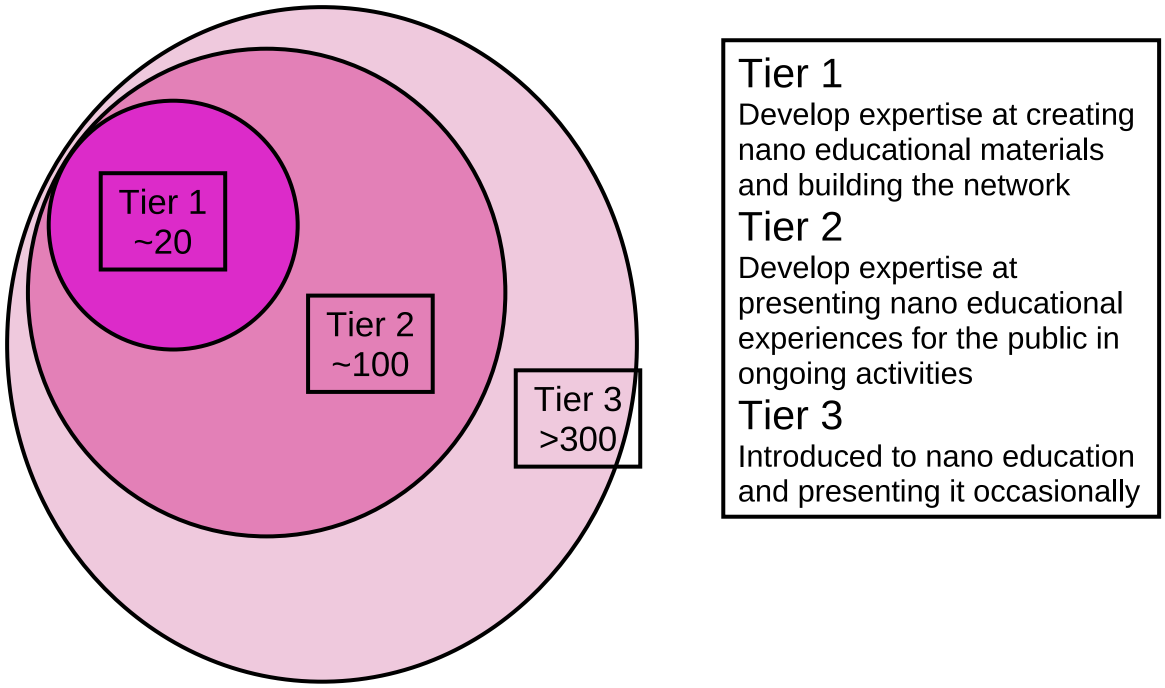

Figure 1.2 Three Network Tiers[36]

The network's internal organization has developed and changed over time as well. My project does not devote itself to tracking these changes, but an overview of the general design of the "working groups" and the methods of collaboration is helpful for understanding the different social groups to which I refer and their role in defining the ISE field. Besides the Network Executive Group and the regional hub leaders, there are various other working groups made up of members from the core partners. This dissertation focuses on the working groups most directly associated with the creation of ArtNano, NanoDays and NanoForums.

The NISE Network programming group, whose conference calls I sat in on for about nine months in 2009, was led by individuals from MRSEC, the Franklin Institute, and the Sciencenter, but also included people from SMM, OMSI, the

[36] Ibid.

Houston Children's Museum, New York Hall of Science, and NCMSL. Throughout the development of the NISE Network, individuals came and went, but for the most part the institutions remained the same.[37] All in all, the programming group calls usually included eight to fifteen people. An offshoot of this group developed NanoDays.

In general, the way the group carried out business was to divide into smaller groups assigned to creating particular programming activities. Then the entire group would give feedback and recommendations via conference calls for further development of the educational guide and materials that had been developed by the subgroup. With most programming activities, one activity was handled by one institution with feedback from a variety of institutions. NanoDays was something of an exception in that their "programming activities" were more complex, so more people participated in the development subgroup, and they conducted additional conference calls separate from those of the Programming Group. The NanoDays group was led by individuals from the Sciencenter, but included other institutions as well. The NanoForums team was made up of eight people from different institutions. There was little breaking up into separate groups, but more parsing out bits of work to different people. The primary people working on ArtNano were called the Visualization Laboratory or Viz Lab. This working group differed from the others in

[37] While I was sitting in on these conference calls, Ft.Worth was transitioning to a new building and was therefore not participating in the program group. Houston Children's Museum was participating, but had not yet been made a core partner.

that the members all originated from the Exploratorium, whereas the other working groups were made up of individuals affiliated with a variety of core partners.

A variety of other work groups have come and gone, or changed names and focus during NISE Net's tenure. There was the Diversity Equity and Access (DEA) group which is now somewhat different in focus and renamed "Inclusive Audiences." There was the Network Community group, which was made up of the regional hub leaders. There is RISE or Researcher Center-Informal Science Education Partnerships. For the most part, members of the NanoForums group or the Programming group splintered off, depending on their interests and priorities, and participated in DEA or RISE as well. Which groups the leaders of Programming and NanoForums chose to belong to gave me an idea of the topics and interests those educators prioritized. For example, many leaders of NanoDays and the Programming Group were also in charge of DEA.

The following summarizes these **Relevant Social Groups.**

Educators: In this chapter I make a distinction between educators who were directly involved in the development of the programmatic activities of the NISE Network and educators who were NOT part of the development of educational modules in NISE Network, but who represent the ISE community which uses NISE Network products. The "educators" are those who use the products, but are not **"organizing members"** of the NISE Network. They participate in the annual NISE Network meeting, in the regional development workshops, and at any regional meetings associated with the NISE Network.

Programming educators: Also known as the "programming group" or "educational programming working group." This is a group of educators within the NISE Network who were directly involved in the planning and implementation of table top exhibits and programs, including NanoDays. This group was led by Rae Ostman from the Sciencenter and was made up of members from all of the Tier One institutions. The group is had approximately 20 members with 10+ participating actively at anyone time.

NanoForums Team: This was the working group which designed and implemented NanoForums. It was made up of six members, one of whom was an evaluator. All members were actively involved.
ISE community or field: This refers to the Informal Science Education community, including all of NISE Network as well as those practitioners not directly related to the Network.
Museum and ISE leaders: This refers to the presidents of the ISE institutions including both museums and professional groups like ASTC.

A Note on Methods

My perspective on the NISE network was challenged by the network's inconsistent response to my presence. For example, I spent about a week in 2008 at the Exploratorium talking with the members of the Viz lab, during which time I had a chance to explain my specific interest in the group. I wanted to join their visualization team and work as a participant-observer during the following spring to try to understand how they had been using images, visualizations, and art to teach their visiting publics about nanotechnologies for the NISE Network. For the first time, I was asked what later came to be a frequently repeated question: Who would I be studying – them or the visitors? I answered that I would be studying them. As it turned out, I did not return to the Exploratorium for participant-observation. After I had returned to New York the project manager informed me that there would actually be little or no image-work going on during my proposed stay. She also said that some members of the team were uncomfortable with the possibility of being subjects of a research study. My access to quotable sources for ArtNano was thus limited by the practitioners' unwillingness to respond to my requests for interviews, or to be interviewed officially, and by the type of work the Viz Lab conducted. Little of its work was uniformly documented, and its personnel turnover rate was high; therefore, few of the current members could talk about the previous work that had been conducted. The group had many scattered or inconsistent goals, priorities and interests and very rarely did those goals line up with the NISE Network's overall priorities. This group seemed to have the most difficulty collaborating with and contributing to the NISE Network. Therefore, I was forced to rely on a variety of informal preliminary interviews, a few more semi-structured oral interviews, and a large variety of online sources organized by the group as representative of their work. Given that there were so many institutional barriers to the ArtNano project within the NISE Network that seemed related to internal issues at the Exploratorium, I worked hard to try to understand, regardless of these institutional issues, how art was perceived, interpreted, and approached as an ISE method. I expanded the chapter to cover work which was not included in ArtNano but was a part of the NISE Network and focused on art and visualization because I was given better access to the resources and creators of these projects.

NanoDays is probably the most visible program of the NISE Network. As such, there was a large variety of resources, formal and informal, documenting its creation, changes over time, and reception. In addition, some of the NISE Network's most detailed evaluation was focused on NanoDays, giving me yet another source of information about the planning, goals, and outcomes of the event. NanoDays was an event which occurred once a year; therefore, I had the opportunity to visit and observe more than one NanoDays event to witness some of its ongoing changes. In addition to the annual festival, NanoDays served as the NISE Network's "traveling exhibit," meaning that the network promoted itself at conferences like ASTC and MRS by having a NanoDays event staffed in some open, shared space of the conference. These conference events did not include all the additional programming that museums often included in their NanoDays events, but they did give me ample opportunity to observe educators presenting and responding to the tabletop exhibits. The organizers of NanoDays granted me interviews on multiple occasions. I was also invited to sit in on the Program Group's conference calls, in which some of the Nanodays planning occurred. I participated in a variety of informal conversations of the Northeast Hub including a professional development workshop held at the Ithaca Sciencenter as well as regional meetings held at the NISE Network's annual meeting.

The chapter on NanoForums relies heavily on oral interviews. The majority of the work of NanoForums had already been conducted, so I had to rely on the group members' recollections of their organizational meetings. Nevertheless, NanoForums, like NanoDays, was heavily documented. A "Forums Manual" was created,[38] similar to the Exploratorium's "cookbooks,"[39] to enable other institutions to create a forums program with the benefit of the expertise and experience of the NanoForums team. NanoForums was also heavily evaluated; therefore, there were a variety of documents assessing the value, techniques, and characteristics of the NISE Network's forums model both as it was happening and after the final version was completed. The NISE

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[38] Brad Herring, ed., "The NISE Network Public Forums Manual" (Museum of Life and Science, Durham, NC for the NanoScale Informal Science Education Network, 2007).

[39] These are how-to guides for exhibits which described exactly what institutions should do to create an exhibit. They are prolific in the ISE field. I did not talk to an educator who was without them on his/her shelf.

Network forums team published a few of their own assessments of NanoForums in *Science Communication* and *The Informal Learning Review*.[40] Also, I was given all of the research files the Forums team had collected as they tried to decide what type of deliberative program they would create. Finally, the NISE Network's online web portal served as an almost unlimited source of documents, evaluations, blogs, and a large assortment of other material related to every aspect of the NISE Network's professional development, evaluation, planning, organization, and distribution of their knowledge and skills.[41]

In addition to the Network Executive Group and the Core Partners, there was an oversight committee called the "Committee of Visitors." This group was primarily an arm of the overall Evaluation working group and only met on occasion. Bruce Lewenstein, who is my committee chair for this dissertation, served on this committee. When I chose the NISE Network as my site, I had no knowledge of his position within it. Lewenstein was also co-chair of the NRC panel that produced the *Learning Science in Informal Environments* report, several of whose members were active in the NISE Network. Although it could be assumed that he held insider knowledge of some sort related to his role in these positions, I never knew about them. In fact, due to his

[40] Christine Reich, E. Chin, and E. Kunz, "Museums as Forum: Engaging Science Center Visitors in Dialogue with Scientists and One Another," *The Informal Learning Review* July/August, no. 79 (2006); Larry Bell, "Engaging the Public in Technology Policy," *Science Communication* 29, no. 3 (March 1, 2008): 386–398.
[41] Anne Beaulieu, "Mediating Ethnography: Objectivity and the Making of Ethnographies of the Internet," *Social Epistemology* 18, no. 2–3 (September 2004): 139–163; Christine M. Hine, *Virtual Ethnography*, 1st ed. (Sage Publications Ltd, 2000). In many ways, my use of these online documents and materials allowed me to conduct a virtual "distanced" ethnography.

worries about the implications of a potential conflict of interest given his position as both my advisor and a practitioner in the ISE community, he hesitated to share with me his experience with the NISE Network or ISE in general.

In many ways, this worry was probably unnecessary, given that students choose advisers based on their expertise in an area pertaining to our research. Dissertation committee members, if they are well-positioned to advise the research, often have not only personal expertise but professional contacts and experiences which relate to their students' work (and often aid students in their attempts to gain access). In the field of science studies, or at least in the Department of Science and Technology Studies at Cornell, there seems to be concern with separating our roles as practitioners and analysts. However, I am not sure, even if this separation is created in the presentation of our research, that we ever truly separate our analyst-selves from the "official" positions we take on to gain access as participant-observers (intern, local sociologist, ethnographer, lab assistant, or volunteer). Perhaps recognizing in our scholarship the challenge of this dual positioning, or situated perspective, would be the most authentic approach to pursue.

Scholarship on science museums

The following analyses outline from a science studies perspective some of the major issues associated with scientific knowledge production, practices, and museums from a science studies perspective. One of the major works, emerging from the "Science, History, Culture" wars, is anthropologist Sharon Macdonald's *The Politics* *of Display: Museums, Science and Culture.*[42] In the introduction to this edited volume, "Exhibitions of Power and Powers of Exhibitions," Macdonald examines the "political nature, uses and consequences of representations of science and technology for the public in exhibitions."[43] Although her work is primarily concerned with exhibitions in museums, and mine is primarily concerned with educational programming as a component of ISE broadly construed, we both demonstrate that public displays of science and technology are productive places to investigate knowledge production. In an article published in Irwin's and Wynne's *Misunderstanding Science?* called "Authorising Science," Macdonald promotes a similar idea, arguing that science communicators do more than move science from one locale to another, serving as "authors of science for the public," "selecting and defining…what counts as science and what kind of entity or enterprise science will be." In addition, especially through their institutional status, science communicators act as "authors with special authority on science," and as such they become "authorisers of science."[44]

Her edited volume, moreover, examines museums and exhibitions that are both historical and contemporary to show that "science displays…have never been just

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[42] Sharon Macdonald, *The Politics of Display: Museums, Science, Culture* (Routledge, 1998), Preface.
[43] Sharon Macdonald, "Chapter 1: Exhibitions of Power and Powers of Exhibition: An Introduction to the Politics of Display," in *The Politics of Display: Museums, Science, Culture*, 1st ed. (Routledge, 1998), 1.
[44] Alan Irwin and Brian Wynne, *Misunderstanding Science?: The Public Reconstruction of Science and Technology* (Cambridge University Press, 1996), 152.

representations of incontestable facts."[45] This premise is one on which my work relies heavily. In addition, Macdonald's work focuses on the assumption that museums are not just putting science on display but creating particular kinds of science for the public.[46] The role of this legitimizing process is one that other scholars have examined as an avenue through which science and scientists maintain and create their cultural authority.[47] Finally, drawing on Foucault, Macdonald sheds light on the relationship among politics, knowledge and power. Macdonald promotes the idea of "public debate about science" as opposed to "public understanding of science" (PUS) as an attempt to move away from the deficit model of PUS as well as public appreciation.[48] Although "public debate about science" was not a phrase my actors used or promoted, the distinction between it and "public understanding of science" is important in explaining how museum educators envision the kind of education and learning their publics should be offered. For Macdonald, public debate about science would enable publics to evaluate the validity and assess the implications and politics of science, in addition to understanding the physical and chemical characteristics of the known universe. Museums would have to accept the potential outcome of increasing public attention to the negative as well as the positive aspects of science.[49]

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[45] Macdonald, "Chapter 1: Exhibitions of Power and Powers of Exhibition: An Introduction to the Politics of Display," 1.
[46] Ibid., 2.
[47] Hilgartner, "The Dominant View of Popularization."
[48] Bruce Lewenstein and Dominique Brossard, "A Critical Appraisal of Models of Public Understanding of Science: Using Practice to Inform Theory." in *Communicating Science: New Agendas in Communication* (New York: Routledge, 2009), 11–39.
[49] Macdonald, *The Politics of Display*, 232.

Examples from her volume support her argument that in order to create such debate museums would have to "disrupt their culturally authoritative role" by promoting and creating exhibitions or displays from particular standpoints, demonstrating controversies, or promoting critical, reflexive, and experimental exhibitions.[50]

For Foucault, power and knowledge are mutually implicated in each other's creation. Power is involved in the creation of truths, while knowledge affects the role of power.[51] Particularly important for my work is the recognition that "knowledge" includes more than just the formalized knowledge of an exhibit or program, but also the knowledges of the variety of parties involved in the making of programming, those parties' attempts to gather knowledge about their visitors, and the knowledge of visitors themselves.[52] Politics, therefore, is not neatly confined to particular policies or institutions, but is represented by the dynamic interaction of power and knowledge as they are constituted, reformulated, and assessed through "social life and cultural practice."[53] This assumption allows me to pay close attention to the actions, knowledge, and intentions of people and materials that are seemingly non-political as important evidence, however indirect, of the interaction and mutual influence of local assumptions and claims, situated inside of wider historically contingent rationales.[54]

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[50] Ibid.
[51] Michel Foucault, *Discipline and punish : the birth of the prison* (New York: Pantheon Books, 1977).
[52] Macdonald, "Chapter 1: Exhibitions of Power and Powers of Exhibition: An Introduction to the Politics of Display," 3.
[53] Ibid.
[54] Ibid., 4.

When I use the phrase "politics of science," I mean to reference this broad sense of power's workings.

Democratizing Science

The process of popularization has been examined as a necessary component of legitimize scientific knowledge-making. The significance of popularization in scientific knowledge production is particularly important for science museums and science centers. Steven Hilgartner has argued that it is the act of popularization of science that legitimizes science. If science were actually to stay shut off and separate from its publics, its power and influence in culture would be marginal.[55] In addition, just as science educators value and qualify science, thereby legitimizing which science their publics should be most aware of, scientists too follow these practices of categorization, organization, and qualification. In fact, without these systems of organization and assessment, neither scientists nor museum educators would be able to build on previous knowledge, set priorities for future study, or demonstrate to others that which has been understood.

Bruce Lewenstein has furthered this argument, which scholars had already begun as early as 1979, "that knowledge does not exist in some ideal state, but exists only insofar as it has been expressed, and each expression produces different knowledge. [For example] an article in the *Astrophysics Journal* is not simply "translated" or "simplified" when the author produces a version for *Sky and Telescope*

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[55] Hilgartner, "The Dominant View of Popularization."

or for a planetarium show, but, rather generates a different instantiation of knowledge."[56]

I choose to rely on these perspectives even though I recognize that unexpressed knowledge may still be knowledge. A secret still exists even if only one person knows of it, but that secret information's relevance, significance, and authority lacks any effective social existence until it is instantiated through the communication process, even if this process is merely the secret-holder's behavioral expression of the stress of keeping a secret.

Museums as Actors

Scholarship with the museum as an object of study serves as a backdrop to understanding the ideologies of practitioners, the practices of institutions, and the professionalization of ISE. For my study, the space of the museum or science center is just one actor among many which take part in the larger project of creating and defining ISE. Nevertheless, that space has had a powerful role in shaping the definition of learning and education in informal science. In *Science in Public,* Gregory and Miller confront the practices housed within the museum space to suggest that through the combination of science museums and science center techniques in which "science centers discard the context and display the principles, and science museums hide the principles deep within historical objects," a more productive

[56] Bruce V. Lewenstein, "Experimenting with Engagement," *Science and Engineering Ethics* 17, no. 4 (November 18, 2011): 817–821, doi:10.1007/s11948-011-9328-5. William D. Garvey, *Communication, the Essence of Science: Facilitating Information Exchange Among Librarians, Scientists, Engineers, and Students* (Pergamon Press, 1979); Shinn and Whitley, *Expository Science*.

strategy of science communication may be reached.[57] Melanie Quin argues that the creation of the museum space itself is "a declaration that government and others want to influence public attitudes to science and technology, and to increase the standing of these subjects (and of scientists, engineers etc.). The museum is a prestigious monument to that aim."[58] Other scholars like Stella Butler argue that science museums' tendency to fail to communicate the complexities and social construction of science is essentially due to the discrepancy between science "as a system of ideas" and "museums," which are about objects.[59] The contemporary practices of museums, although no longer relying as heavily on objects, demonstrate the legacy of this tendency. Even in spaces that do not collect or depend wholly on collections as a means of communication, the assumption remains that complex social aspects of science are not part of what is put on display.

The representation of science and its implications for the authority of an ISE institution is another theme in this literature that is important to this dissertation. Macdonald argues that "this unchanging representation of science in the museum may not only misrepresent the changing face of science, but may also exaggerate the authority of the institution and its contents."[60] Perhaps ISE institutions need to be willing to relinquish some of their authority if they are to incorporate portrayals of emerging science and technology into their repertoires. In *The New Museology*, Peter

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[57] Jane Gregory, *Science in Public: Communication, Culture, and Credibility* (New York: Plenum Trade, 1998), 210.
[58] Quoted in: Jane Gregory and John Durant, *Science and Culture in Europe*, English language ed (Science Museum, 1993), 196.
[59] Butler, *Science and technology museums*, xi.
[60] Irwin and Wynne, *Misunderstanding Science?*, 152.

Vergo argues for a “radical re-examination of the role of museums” with particular emphasis on “Contexts: Spaces and Times, Contests: Identities and Differences, and Contents: Classification and Practice.”[61] Vergo’s edited volume insists that the museum as a space, its objects, the practices which organize those objects, and the identities of the people (practitioners and visitors both real and imagined) must be examined as actors working in concert. My study pays close attention to the prioritization of the needs of practitioners and visitors and the role of those priorities in shaping the work of ISE institutions. As Macdonald argues, it is essential to “account for museums theoretically as contextualized and contextualizing, and as having content not just to their displays, but also to their form and institutional practice.”[62] My work incorporates the programmatic deliverables of the NISE Network as well as the field’s institutional practices, historically and contemporarily, and the negotiation between individual institutions and the network as a whole to try to understand not only how and why certain kinds of knowledge are made, but how that knowledge travels and changes as the context changes.

Democracy, Science, Museums, and Visitors

A large portion of this dissertation tries to unpack the relationship between the museum as a site of learning and education, the development of the ISE field, representations of emerging technoscience, and democracy. In particular, scholars have tried to understand what the rise of visitor studies tells us about the museum

[61] Vergo, *The New Museology*, 3.
[62] Sharon MacDonald, *A Companion to Museum Studies* (John Wiley and Sons, 2010), 8.

community. Many argue that a shift is underway. "The shift is from simply conserving culture to also communicating it; from advocating science to debating it; from the museum as a bank vault of the history of science to the museum as a living treasure trove of the scientific culture in which all can share. This emphasis on the public context in which their efforts are judged is a change that today's museums ignore at their peril."[63] The problem with Visitor Studies is that it still does not acknowledge head-on that "it would be easy to conduct a study in which one finds that museum visitors did not notice any of the exhibits and left having acquired no new facts about science."[64] This, in fact, was the result of one of the NISE Network's evaluations of the NanoDays program (see Chapter 3).

What then is the relationship between the variety of practitioners' visions of and goals for visitors and visitors' own abilities and goals? Cozzens and Woodhouse provide a short history of the "naive" notion that "citizen participation will somehow hold the experts accountable."[65] In fact, as other STS scholars have noted, "much of what passes as 'participation' in current governance can be…understood as attempts by the powerful to co-opt the public."[66] Avoiding this co-opting is exactly what many museum professionals argue to be their rationale for presenting science as unchanging and uncontroversial. Keeping the museum removed from the politics of science

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[63] Gregory, *Science in Public*, 214.
[64] Ibid., 213.
[65] Susan E. Cozzens and Edward J. Woodhouse, "The Politics of Knowledge," in *Handbook of Science and Technology Studies*, ed. Sheila Jasanoff (SAGE, 1995), 545.
[66] Dorothy Nelkin and Michael Pollak, *The Atom Besieged: Extraparliamentary Dissent in France and Germany* (MIT Press, 1982).

enables museums to contribute to a type of learning and education that is supposedly beneficial but frequently not effective.[67]

Dickson in *The New Politics of Science* made a similar point about "technology assessment." Democratic participation in the selection of technical choices requires a shift in control that the scientific, corporate, and political establishment is not willing to make.[68] A tension, therefore, exists between the goals of the scientific establishment and its support of ISE, and the implications for ISE if its work motivates any sort of shift of power which may seem to undermine the authority of the scientific establishment. My dissertation examines the role that this threat of a possible power shift plays in practitioners' practices and goals.

Another argument frequently made by the practitioners observed in this study who did not want to participate in science communication strategies that could empower publics in debate about science is that "the public is neither interested nor competent in the governmental matters scientists deal with."[69] However, "dozens of studies of scientific controversies have tracked the involvement of citizens in issues they perceive as direct threats to their everyday lives."[70] Citizens can acquire a great deal of technical knowledge, when they need it. This dissertation tries to document

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[67] Macdonald, *The Politics of Display*, 152.
[68] David Dickson, *The new politics of science* (New York: Pantheon Books, 1984), 259.
[69] Cozzens and Woodhouse, "The Politics of Knowledge," 546.
[70] Frederick Frankena and Joann Koelln Frankena, *Citizen participation in planning : a bibliography* (Chicago: Council of Planning Librarians, 1988); Dorothy Nelkin, *Controversy : politics of technical decisions* (Newbury Park, CA: Sage, 1992); James C Petersen, *Citizen participation in science policy* (Amherst: University of Massachusetts Press, 1984); Charles Piller, *The fail-safe society : community defiance and the end of American technological optimism* ([New York]: BasicBooks, 1991).

the tensions in ISE over its role in helping citizens acquire technical knowledge expressly for "empower[ing]" citizens.

Another line of criticism by practitioners directed against the role of politics in science museums relates to the separation of technologies from science. Scholars argue in relation to such controversies that scientists who view "local controversy" as "antiscience" are mischaracterizing citizen interests. In fact, although many controversies seem as though they are about the politics of technologies, rather than the politics of science, "the authority of science is inseparable from its applications when seen through the eyes of the citizens" who make up these "local controversy" movements.[71] Cozzens and Woodhouse argue that these movements should more accurately be "called 'proknowledge,'" because each movement seeks in part to revalue forms of knowledge that professional science has excluded rather than to devalue scientific knowledge itself.[72]

> A range of citizen actions across many spheres of government, from courts through regulatory agencies to research sponsors, all share the implicit goal of reestablishing the legitimacy of knowledges other than professional ones…controversies and events that seem, from the viewpoint of the research community, like either threats to academic freedom or petty nuisances are reinterpreted, in the STS view, as part of the politics of knowledge.[73]

In fact, ISE practitioners can rest assured that the knowledge they produce for their publics will not be taken up unequivocally by those publics. For example, Sheila

[71] Cozzens and Woodhouse, "The Politics of Knowledge," 547.
[72] Ibid.
[73] Ibid.

Jasanoff has argued for the recognition of pathways through which cultures test knowledge claims. Unlike the assumption by some educators that their visitors will just accept at face value any argument the museum or institution makes at face value, Jasonoff's concept of "civic epistemology" points out that information will be interpreted and judged through a set of "tacit-knowledge ways." She argues that the "institutionalized practices by which members of a given society test and deploy knowledge claims [are] used as a basis for making collective choices." She insists that today's modern technoscientific cultures have developed practices "to assess the rationality and robustness of claims that seek to order their lives; demonstrations or arguments that fail to meet these tests may be dismissed as illegitimate or irrational."[74]

Taken together, this literature helps us to understand some of the ways scientific knowledge production occurs in more public forums like museums and the challenges and potential that a public forum of scientific knowledge production can hold for practitioners and publics. These scholars present evidence for popularization as knowledge production, opening up space to assess the role ISE plays in this popularization. In addition, emerging technologies like nanotechnology serve as sites of contestation that are not yet embroiled in the entrenched politics of older controversies. The potential of educational practitioners and citizens to participate in the shaping of these new technologies is more legitimately extended beyond the case study, when the study is not put under the public eye of controversy.

[74] Sheila Jasanoff, *Designs on Nature : Science and Democracy in Europe and the United States* (Princeton N.J.: Princeton University Press, 2005), 255.

Although some scholars have argued that controversies can serve as good sites to view the interaction of the significant social groups involved in science that is still in the making, I argue that the stress of public controversy on the actors actually impairs our ability to recognize business as usual and the practices, ideologies, and materials that play the greatest roles in informing that "usual business" in the long term.[75] I am interested not just in how beliefs become true or false but how those practices, ideologies, and materials serve to shape professional practices and expectations that define some beliefs as more true or as holding a higher priority.[76] Examining emerging practices surrounding current science and technology provides an opportunity to assess how closure happens or if it happens without the need for a controversy.

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[75] H. M Collins, *Changing order : replication and induction in scientific practice* (London; Beverly Hills: Sage Publications, 1985); H. M Collins and T. J Pinch, *The golem : what everyone should know about science* (Cambridge [England]; New York, NY, USA: Cambridge University Press, 1993).

[76] Brian Martin and Evelleen Richards, "Scientific Knowledge, Controversy, and Public Decision-making," in *Handbook of Science and Technology Studies*, ed. Sheila Jasanoff (SAGE, 1995).

CHAPTER 2
ART, ARTISTS, AND THE WRONG KIND OF SCIENCE EDUCATION

Introduction

Artistic methods are both valuable and controversial tools for establishing a public engagement with science.[77] Museum educators, as well as artists, scientists, and even professional science societies have seen art practices as alternative yet valuable options for teaching and learning about nanotechnologies.[78] This chapter documents the creation of the ArtNano program by the Exploratorium's Visualization Laboratory (Viz Lab) and the role art methods played in defining the purview of the NISE Network. According to the NSF, the success of the NISE Network depends in part on the ability of practitioners from a variety of institutions with different expertise to share their institutional know-how to create educational modules that can be

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[77] There are a number of studies which define public engagement. For this study, the definition of public engagement originates from the practitioners, sometimes in contrast to current scholarly definitions of public engagement. See, Bell, "Engaging the Public in Technology Policy"; Ellen McCallie et al., "Many Experts, Many Audiences: Public Engagement with Science and Informal Science Education," *A CAISE Inquiry Group Report* (2009): 1–83.

[78] Of course it depends how we define "art practice", but a few examples, though there are numerable, include: The Exploratorium's "Artists Visualizing the NanoScale", 2006, http://www.nisenet.org/artnano/ ; Science Museum of Minnesota is a leader in science theatre with their "Science Live Theatre" and its nanorelated pieces; and scientists like Eric Heller who is a Harvard physicist but shows his "art" both online and at many other museums, science societies, and art festivals.

See also: "Art Nano | NISE Network," accessed September 12, 2012, http://www.nisenet.org/artnano. and Addeane Caelleigh, "Roles for Scientific Societies in Promoting Integrity in Publication Ethics," *Science and Engineering Ethics* 9, no. 2 (June 1, 2003): 221–241, doi:10.1007/s11948-003-0010-4.

distributed and used at all types of science museums and centers.[79] In the case of art practice, that proved difficult.

This chapter demonstrates that several factors, including NSF-mandated statistical evaluation and conflicting ideologies regarding what counts as worthwhile informal science education about emerging technologies, contributed to the quick demise of the ArtNano program. I argue that art methods as science education maintained a low priority within ISE because those methods did not fulfill the current NSF-backed definitions of informal science education. I demonstrate that the more abstract, open-ended, or critical the art practice, the less likely it was to be taken up and distributed by the network, in effect selecting out the knowledge of artists as valid forms of scientific knowledge.

This chapter is divided into three parts. The first examines some competing visions of nanotechnology represented by different approaches to nanoart,[80] while the second tries to understand the variation among differing visions in how they contributed to informal science education focused on emerging technologies. The third part then examines in detail the work of the Visualization Laboratory or Viz Lab. Overall, this chapter argues that the artists and scientists who collaborate to produce nanoart contribute to education and learning about emerging technologies in informal

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[79] *Nanoscale Science and Engineering Education (NSEE) Program Solicitation* Program Solicitation (National Science Foundation, January 6, 2005).

[80] Here and elsewhere "nanoart" is the term I use to refer to art, of a variety of genres or media, whose content is nanotechnology-focused. This should not be confused with other similar terms such as: *ArtNano,* a programming effort of the Visualization Laboratory, or Cris Orfescu's *NanoArt* or *NanoArt21*, both of which are different instantiations of exhibitions or movements coined by Orfescu.

environments, even if their definition of education does not fit that of the NSF or the NISE Network. The Exploratorium case is a detailed example of the overall argument. Despite the Exploratorium's long history of expertise in the area of dissemination of educational plans and products, the Viz Lab failed to create deliverables that were distributable to the NISE Network.[81] Therefore, I examine the factors that combined to produce simple and seemingly distributable products which were nevertheless not fully taken up by the Network. I show how those factors played a role in defining, for museums that are new to working with emerging technologies, what counts as the right kind of educational methods to address this new subject.

After the first year of the NISE Net project, the Network was optimistic, at least on paper, about the role the Viz Lab work would play.[82] However, by 2007 and 2008, it had become clear that the work of the Visualization Laboratory was not going to play as important a part in the Network as had originally been intended. In spite of some ideas that the Viz Lab practitioners found interesting and exciting, the final products of their labors, which had been directly requested by the Network, were not recognizable for other science educators as valuable forms of science education when the modules and methods were not based in traditional laboratory learning.[83] I

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[81] The model for distributing exhibits was the Exploratorium's line of "cookbooks," organized exhibit construction manuals that are available for a reasonable price and include directions for how to build hundreds of exhibitions. See also, Hein, *The Exploratorium*.

[82] Larry Bell, *1st Annual Report (NISE Network): 10/2005-09/2006* Annual Report, Year 1 (Boston, MA: National Science Foundation, June 30, 2006).

[83] See detailed section of this chapter on the Visualization laboratory and Diane Burk, "Visualization Laboratory Group Meeting" interview by Kathryn Vignone, June 2008.

examine how the products that the NISE Net requested of the Viz Lab failed to demonstrate to other educators how these educational modules, or art exhibitions, could fit into their own institutions' programming and priorities.

This chapter illustrates how choosing not to include art practice as a method for the larger network allowed the NISE network to pursue educational methods that could fit into the evaluation strategies required of them by the NSF. Not including art practice, which was often more open to content focused on portraying technologies as part of and a response to culture, also meant that visitors and educators new to emerging technology content in museums would not necessarily associate that new content with its cultural context. Also, art practices, to greater and lesser degrees, represent science as a part of culture. I argue that not including art practices in science education was one of the ways that the Network avoided addressing social and ethical considerations in its programming.

Competing Visions of Nanotechnologies

The Exploratorium story can be understood by establishing a context with four other informal science education art-nanotechnology activities, which show the primary genres of nanoart exhibitions. This context will help illuminate the role the relationship of the NISE Network to the NSF may have had on the goals, focus, and methods of the Visualization Laboratory. In many ways, these four types of art exhibition serve as possible methods of educating publics about emerging technologies that the Viz Lab could have pursued and in some cases did consider when trying to determine which art and visualization methods to integrate into the work of the NISE Network.

The following is a brief description of the four genres, which will each be described in more detail in ***Part II*****:**

> ***NANO***
> Artist Victoria Vesna and nanoscientist Jim Gimzewski created *NANO*, an immersive media art exhibition first displayed at the Los Angeles County Art Museum in 2004. The exhibition focuses on dissolving disciplinary boundaries between media art and nanotechnology in order to help visitors understand their ability to contribute to scientific and cultural production.
>
> ***Science as Art***
> The Materials Research Society (MRS) sponsors *Science as Art*, a semi-annual competition whose purpose is to gather and display nanotechnological portraiture created by the society's meeting participants. The exhibition serves as a part of the MRS's public engagement and outreach activities, hyping nanotechnology's future through the display of aesthetically pleasing images.
>
> ***NanoArt***
> Artist, scientist, and promoter Cris Orfescu organizes the now-annual, international display of the "NanoArt movement" through an online art competition and art gallery exhibition. The exhibitions promote the belief that nanotechnologies play an important role in society and encourage public action in relation to the possible future risks that nanotechnologies pose.
>
> ***Sites Unseen: An Educational Art Show***
> **I**nterns in the University of Wisconsin-MRSEC's **P**ublic **S**cience **E**ducation (IPSE) program organized this coffee shop art show in downtown Madison in 2008. In an attempt to bring science to places where people do not usually expect it, the IPSE curators exhibited fourteen materials research images and seven complementary, explanatory diagrams which

> they designed to try to introduce the human and aesthetic side of science.

These four different types of nanoart exhibition demonstrate attempts by artist- and scientist-educators to intervene in the current trajectories of public knowledge of nanotechnologies. I argue that these artists and scientists perform as educators to exert the institutional power and practices of art, science, and museums in an attempt to connect to and empower "the public"[84] to shape what nanotechnology will become.

Few previous studies have examined the intersection of physical places (e.g. museums) and digital spaces (e.g. websites) where educators use art practices to engage non-scientists with emerging technologies. Of those studies that do take the public as a focus, most have tried to assess the "public's" knowledge of nanotechnology and attitudes toward it, often focusing on print media. Others have examined the specific role that newspapers play in "framing" nanotechnology research and assessing its risks.[85] These studies argue that the U.S. public believes itself to be

[84] For the purposes of this chapter, I am not critiquing what counts as the public or publics, though I am aware that this could make up another section of this chapter (or, indeed of the entire dissertation). Instead, I try to make clear when the actors do or do not define who they see as their visitors or publics. For the most part, the visitors, viewers, and imagined publics of these exhibitions include: museum visitors, scientists, policymakers, other artists, and those unaware of nanotechnology.

[85] Matthew C. Nisbet and Chris Mooney, "SCIENCE AND SOCIETY: Framing Science," *Science* 316, no. 5821 (April 6, 2007): 56, doi:10.1126/science.1142030; C. Wikinson et al., "From Uncertainty to Risk?: Scientific and News Media Portrayals of Nanoparticle Safety.," *Health, Risk, and Society* 9, no. 2 (n.d.): 145–157; Alison Anderson et al., "The Framing of Nanotechnologies in the British Newspaper Press," *Science Communication* 27, no. 2 (December 1, 2005): 200–220, doi:10.1177/1075547005281472; Mary F. E. Ebeling, "Mediating Uncertainty:

largely ignorant of nanotechnology and its potential.[86] However, this same public supports nanotechnology research and funding. Scholars have thus begun to understand, given the kinds of publics in the United States, how those publics are important in shaping nanotechnologies as they develop.[87] Nevertheless, previous investigations provide only a narrow perspective, given that a large proportion of nanotechnological content is available via digital and exhibitionary forms.[88]

The scholars, activists and policymakers central to existing studies of nanotechnology have predicted what a world with nanotech will be like or should be like, and in so doing have contributed to what nanotechnology *is* like.[89] Many of them

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Communicating the Financial Risks of Nanotechnologies," *Science Communication* 29, no. 3 (March 1, 2008): 335–361, doi:10.1177/1075547007312068.

[86] Margaret Glass, "The NISE Net: Bringing the Study of the Very Small to US Science Centers," *PLoS Biol* 5, no. 10 (October 16, 2007): e283, doi:10.1371/journal.pbio.0050283.

[87]See, R.a.J.S. Berne, "Teaching Societal and Ethical Implications of Nanotechnology to Engineering Students," *Bulletin of Science Technology & Society* 25, no. 6 (2005): 459–468. for a study that examined focus groups (like engineers) and effective ways to improve their ability to assess the risks of nanotechnology through science fiction.

[88] Mainstream movies like *The Incredible Hulk* or *Spider Man* and a variety of online databases, like Robert Freitas' *Nanomedicine gallery,* have contextualized visual and discursive images of nanotechnology. Newspapers tend to be light on images of nanotechnology, whereas popular science fiction like Michael Crichton's *Prey*, popular science magazines like *SEED*, and a variety of online blogs, research groups sites, and professional science society databases contain extant nanoimagery. See also: Colin Milburn, *Nanovision: Engineering the Future* (Duke University Press, 2008); Daniel Patrick Thurs, "Tiny Tech, Transcendent Tech Nanotechnology, Science Fiction, and the Limits of Modern Science Talk," *Science Communication* 29, no. 1 (September 1, 2007): 65–95, doi:10.1177/1075547007306340.

[89] For a few examples of scholars who have specifically addressed image-based communication pathways through which a science or technology is instantiated see: D. Nelkin, *Selling Science: How the Press Covers Science and Technology* (New York: W.H. Freeman and Company, 1995); Dorothy Nelkin and M. Susan Lindee, *The DNA Mystique: The Gene as a Cultural Icon* (University of Michigan Press, 2004);

have served as mediators for an imagined public. In contrast, the artists and scientists in the following vignettes do not try to predict nanotech's future; instead, they create a means through which *publics* can envision and entertain that future. I refer to "publics" plural to emphasize the diversity of individuals and groups included in this reference and to account for the unpredictability contained within this diversity. "Public" presumes one unified group, with shared responses and interpretations, where as "publics" allows for the less predictable possibilities inherent in constantly changing perspectives.

With the increased visibility of nanotechnology in society, artists have begun to create art works and exhibitions about nanotechnology. This art has taken a limited variety of forms— mostly immersive media experiences or digital two-dimensional creations— but has served a larger variety of purposes. In fact, there is more variety in the purposes of the artworks than in the forms.[90] Much of what is currently called "nanoart" poses questions about the meaning and trustworthiness of visual information, the future possibilities of proposed nanotechnologies, or the risks associated with powerful technologies. A large percentage of this art is available online.

Celeste Michelle Condit, *The Meanings of the Gene: Public Debates About Human Heredity* (University of Wisconsin Press, 1999); Milburn, *Nanovision*; Thurs, "Tiny Tech, Transcendent Tech Nanotechnology, Science Fiction, and the Limits of Modern Science Talk."

[90] It might be safer to say that "variety" is a relative term. There is more variety in purposes of the nanoart than in the form, but given that there is not a whole lot of variety in form, that may not be that impressive. Most importantly, even though the artists who create this nascent nanoart have not used a huge variety of forms, they do vary more in their beliefs and purposes associated with their art.

Some of these online spaces are materialized in the galleries of art and science museums or in books or catalogs, although their presence remains most dominant in digital online forms, particularly in online galleries. There have been a small handful of immersive digital experiences which focus on nanotechnology or at least nanotechnology-related themes.[91] All of these different methods of presentation can also be divided into two categories: those that require an actor to participate physically or at least actively in the exhibits, and those that do not require such interventions by viewers, participants, or visitors.

As early as 1979, a survey by the Institute of Museum Services revealed that 45% of all museum visits were to science museums as compared to 24% to history museums and 12% to art museums.[92] This trend means that nanoart has the potential for a much higher exposure rate in science museums than in art museums. In addition, if the "general museum-going public" is a place holder for somewhat more specific groups like policymakers, educators, and other interested parties whose job it is to understand and ascribe meaning to nanotechnology for others, then artists whose work is displayed in museums can claim that their work reaches those publics.

The following section of this chapter describes the nanoart practices of four different groups paying particular attention to their conceptions of art and science to illustrate how these practitioners' attempts to make nanotechnology public reveal both

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[91] Victoria Vesna and Scott Snibbe are two of the most prominent examples of artists who rely on immersive digital techniques.

[92] The National Center for Education Statistics, *1979 Museum Universe Survey* (Washington, D.C.: Institute of Museum Services, 1980).

the role art can play in portrayals of nanotechnology and its role in defining science education.

Methods and Vignettes

This chapter orients what information was available about the Viz Lab (through informal interviews, NSF annual reports, and online archival documentation) with respect to other examples of art and nanotechnology educational collaborations. I drew from a range of materials to explore these four representative examples, which included changes over time in the online presence of the exhibit and/or group hosting the exhibition, oral interviews of the exhibitions creators (when possible), and in person observations of the exhibits (when possible). I conducted critical and conversational discourse analyses of my materials to examine how language demonstrates assumptions, beliefs, and intentions about social power, particularly the role art plays in challenging possible power imbalances. I analyzed *NANO's* catalog[93] in addition to Katherine Hayles' collaborative book with a chapter on the exhibition with the same title,[94] as well as and formal and informal discussions with one of the primary designers of the exhibition conducted during conferences and workshops where she was presenting. My analysis of *Science as Art* relies on an analysis of the online archive of the past exhibitions, provided by the MRS official website. In addition, I conducted informal interviews with artists and organizers while visiting the exhibition held during the MRS semi-annual meeting in Boston in December of 2009.

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[93] Victoria Vesna and James Gimzewski, "NANO: At the Intersection of Art and Science" (Los Angeles County Museum of Art (LACMA) Lab, September 14, 2003).
[94] N. Katherine Hayles, ed., *Nanoculture: Implications of the New Technoscience* (Bristol, UK: Intellect Books, 2004).

My analysis of *NanoArt21* draws on the online website and exhibition space, along with an informal interview with Cris Orfescu. Lastly, for *Sites Unseen,* I traveled to Madison, Wisconsin to view a simplified version of the exhibition in the Madison Airport and also relied on interviews with two of the primary organizers and the archived online material provided by UW's MRSEC.

This chapter treats these examples as "vignettes" rather than "case studies" and views them as a means of contextualizing the work the Exploratorium's Viz Lab accomplished and documented. I present them in an attempt to delineate the range of definitions of informal science education found in exhibitions which use art methods in order to shed light on what science education can look like if art methods are considered valid and productive ways to learn (See Table 2.1).

Table 2.1 Summary of media and purposes

Exhibition	Media/Contributors	Educational goals and knowledge construction
Nano	Immersive media art made collaboratively by artists, scientists, and others for and with visitors	Visitors' presence, physically and mentally "complete the experience" thereby making connections and creating knowledge themselves which is then fed back into the immersive experience
MRS: Science as Art	Digital prints made by scientists for science (originally), then promoted by scientists for public outreach	Viewers recognize the importance of science through exposure to beautiful, recognizable (and thus interesting) science
NanoArt	Digital prints made by artists drawing from scientific images and content	Scientists as artists as communicators reflect on nano's role in society for each other and for viewers to provide an alternative portal through which people can access, comment on, and create relationships between science and society

Sites Unseen	Digital prints made by scientists for science, images are selected by education interns	Viewers who are assumed to not ordinarily be exposed to science learn about it through art; in a more casual setting, these viewers make connections between their knowledge and the new knowledge of the prints, thus revealing to the designers' relationships between science and culture they previously did not know

The following section details four exhibitions – *NANO*, *Art as Science, NanoArt21, and Sites Unseen* - as four different genres of nanoart. Their media and their learning purposes represent a range of art practices of current nanoart that could potentially be employed in science education.

NANO

UCLA media arts professor Victoria Vesna, in collaboration with UCLA chemist James Gimzewski, headed the team of architects, media artists, and graduate students from the sciences, arts, and humanities who all contributed to the design and implementation of *NANO.* The exhibit opened in the Boone Children's Gallery of the Los Angeles County Museum of Art in 2003.

Vesna and Gimzewski describe the exhibit as "modular, experiential spaces using embedded computer technologies in an attempt to activate a sensory experience that creates an understanding of both nanotechnology and its cultural implications." The individual installations or galleries, linked together to form the overall exhibition, immerse visitors in sensory and scale contradictions, which the designers believe to be characteristic of the nanoscale. Visitors are supposed to find themselves feeling what it is like to manipulate materials one atom at a time or experiencing the ordinarily invisible through interactions with space. The 10,000-square-foot exhibit contains a web of galleries where one gallery's results feed the content of another or, in other words, one visitor's experiences contribute to another visitor's experiences in a different, but connected space. This creates the possibility that no walk through the exhibit is ever identical to the next.

Knowledge of the physical characteristics of the nanoscale is created as the visitors react to and feed into one another's experiences via the immersive technology. *NANO* purposely contains no directed path through its spaces. In the accompanying catalogue[95] the designers articulate their philosophy of exhibit design:

> Nanoscale science and media art are powerful synergies that can promulgate the 21st century emergence of a new 3rd culture, embracing biologically inspired shifts, new aesthetics and definitions. *Nano* is meant to be a first step in creating a space where asking questions is part of the experience rather than being told the "facts." At this stage, imagination is needed to envision the future use of this new science and everyone is invited to participate.[96]

Nano literally gives its visitors not just new objects to interact with, but new spaces to experience and create.

Science as Art

In 2005, the Materials Research Society staged the first *Science as Art* competition at their semiannual meeting in San Francisco. In this ongoing project, the

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[95] Vesna and Gimzewski, "NANO: At the Intersection of Art and Science." This catalog, available to the public online as a 78-page PDF, is an artist's statement that includes images and descriptions of the individual galleries as well as the designers' philosophies of design and learning.

[96] Ibid., 7.

meeting's participants (scientists) are invited to submit images that contribute to the "Science Component" of the meeting, but which the organizers believe hold meaning beyond the scientific. In the call for submissions they describe the broader role of materials research images. "Occasionally, scientific images transcend their role as a medium for transmitting information and contain the aesthetic qualities that transform them into objects of beauty and art." It is unclear what kind of learning is supposed take place if once the images become "objects of beauty and art," their purposes goes beyond "transmit[ing] information." However, the exhibition was put together to serve the Education Outreach component of the MRS's activities and perhaps in this case the medium is the message. As "objects of beauty and art," maybe they transmit different information.

Prior to the meeting, participants submit their scientific portraiture to the Meeting Chairs. The Chairs choose Finalists whose work is displayed at the meetings, where meeting participants select the final winners. These images are printed in high resolution with dimensions no smaller than two by three feet. Nanoimages are printed the size of posters. It is clear when visiting this exhibition that the organizers conceive of the exhibition as being an extension of the other meeting activities, like the poster session. Though they state that the images "transcend their role as a medium for transmitting information," the images are printed on surfaces similar to the posters in the next room. I noticed that whereas the posters from the general sessions are generally made up of images and text too small to read, the posters of the art exhibition are filled only by an image that is normally too small to see.

The MRS has a history of devoting time and resources to outreach activities; the most notable example of its efforts is a traveling exhibition, *Strange Matter.*[97] It maintains a standing "Public Outreach Committee" which

> develops activities and programs on both national and local levels to educate the general public on materials research and its importance. Activities and programs may include, but are not limited to, pre-university science education, press communications, and public service information.[98]

This committee "evaluates, interprets, and communicates the *impact* of the Society's public awareness programs to the Board of Directors and the Board's External Relations and Volunteer Involvement Committee."[99] *Science as Art* serves scientists as well as informal science educators by acting as a source of high-resolution, digital images of nanoscience and materials research which have been selected to demonstrate how science can have value beyond what is traditionally considered "scientific value."

NanoArt

Cris Orfescu is an artist and technologist who has become a self-described pioneer in the movement he describes as "NanoArt." In addition to producing his own art, Orfescu has organized and promoted a nanoart exhibition to provide other artists working in nanoart, a forum in which to display their work and a vehicle for

[97] *Strange Matter,* http://www.strangematterexhibit.com/, is a hands-on exhibit for children and families that has traveled to science centers throughout the U.S. and Canada.

[98] Materials Research Society, "Public Outreach - Materials Research Society," 2010, http://www.mrs.org/public-outreach-committee/.

[99] Materials Research Society, "Materials Research Society Operating Committees," 2010, http://mrs.dev.berndtgroup.net/committees/.

promoting the "movement." Beginning in 2006, Orfescu designed an online gallery where participants can submit and display their nano-artwork and working philosophies, which include motivations for the pieces as well as information about the artists' personal backgrounds.

Many of these submissions begin their journey in a laboratory; they are the products of nanoimaging technologies like scanning tunneling microscopes or scanning electron microscopes. However, their final forms are artists' renditions, using nanoscience (rather than more traditional materials like paint, ceramics, etc.) as the medium. Importantly, many of these artists are also scientists, but for the purposes of the competition Orfescu emphasizes and validates the work that they produce when performing as artists. As artists, they have the authority to comment on and produce nanofutures.

NanoArt's finalists, having submitted their work electronically, are then invited to display their work at a physical gallery exhibition that Orfescu organizes.[100] The images are printed on canvas or other permanent surfaces, framed, and hung at the exhibition opening. Orfescu describes the *NanoArt* movement and the role it can play in shaping nanotechnology on the web portal which hosts the online portion of this competition.[101]

> NanoArt is the expression of the New Technological Revolution and reflects the transition from Science to Art using Technology. Scientists are exploring the nano world hoping to find a better future and there is evidence

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[100] *NanoArt* has exhibited its artists since 2007 in galleries in Finland, Germany, and the Czech Republic.

[101] "NANOART 21," 21, accessed September 12, 2012, http://www.nanoart21.org/.

> that Nanotechnology might be the answer. Like any new technology, Nanotechnology can have positive or negative effects on the environment and society. Artists should familiarize the general public with the nano universe, so people will focus on the positive effects and redirect the negative ones to benefit from them.[102]

For Orfescu, artists have a responsibility to mediate nanotechnology for "the general public." He seems to argue that in the same way that nanotechnology may be the beginning of a scientific revolution, *NanoArt* may serve as the origin of a new cultural revolution in which artists wield technologies to transform science into art. Art then serves as valuable knowledge about science. This art can function to educate publics specifically about how they can benefit from nanotechnologies. These publics must take advantage of the beneficial aspects of the new technologies while determining ways to not just allay the detrimental effects, but to change those negative effects into benefits. This is a big task, and it is unclear how these digital prints can produce such a dramatic effect on viewers. It is too soon to know yet whether the art and artists of *NanoArt* will have a long-term impact on society, but the existence of the site and its associated events stands as proof of the potential impact of nanotechnologies in culture and artists' authority to affect that impact.

Sites Unseen: An Educational Art Show

During the fall of 2007 and the spring of 2008, the Interns of Public Science Education (IPSE) program at the University of Wisconsin-MRSEC organized an art exhibition at a Madison coffee shop using fourteen images of materials science

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[102] Cris Orfescu, "NanoArt: Art/Science/Technology," *NanoArt International Online Exhibit*, 2010, http://www.nanoart21.org/html/nanoart.html.

research provided by MRSEC scientists. For half of the images, the interns developed accompanying "educational graphics" to assist viewers in interpretation. The images were put on display with an accompanying "artist" statement, explaining the research and personal background of the scientists who submitted them. The goal of the exhibition was to display to a public unaccustomed to viewing science in their everyday lives that:

> Science imagery can be aesthetically pleasing; Interesting scientific phenomena are happening below the visible threshold; Science images can be made understandable by accompanying educational graphics; and Science is a "people" story.[103]

In May 2008, while the show was on display, the interns interviewed over a hundred coffee shop patrons to gauge "public interest and understanding of the images, as well as the public's overall interest in science and the art show as a whole."[104] They found, to a great extent, what had already been well-established in science studies literature: when provided with images of science for which they have no prior concepts to help them understand, viewers will interpret those images based on the concepts they do have. For instance, many of those interviewed told the interns that one of the images reminded them of a picture of the isthmus on which Madison sits, a connection the interns had never made before.

Analysis: Variation in the Visions

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[103] "IPSE Project Descriptions | Sights Unseen: An Educational Nanoart Show," *IPSE: Project Descriptions*, 2008 2007, http://mrsec.wisc.edu/Edetc/IPSE/about/projects.html.
[104] Ibid.

NANO, Science as Art, *NanoArt* and *Sites Unseen* portray distinct perspectives on how art can be used to engage the public, what it means to engage the public, and what methods of the art world have the most potential to give power and authority to nanoartists, nanoscientists, and nanoresearch. In turn, these examples show that the nanoscience community, through its participation in interactive exhibitions and sponsorship of image competitions, believes that art can be an important and effective educational tool to shape the identity and significance of nanotechnology. These works show not only how science as art empowers the public, but also how science as art maintains science's and nanotechnology's social position by appropriating art's cultural capital.

The four examples are exemplars[105] of a larger pattern of nanoartists creating, promoting, and organizing nanoart because they believe that publics can and must participate in shaping what nanotechnology becomes, whom it affects, and how it is used.[106] Artists often use stabilized science and technology as their subjects. Nanotechnology, however, has not yet become pervasively visible in society. These artists seem to believe that if they use nano as the subject or medium of their art in the

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[105] ALESSANDRO SCALI, "ALESSANDRO SCALI ::: NANOART: Alessandro Scali & Robin Goode's NANOART on NATURE," *Nanoart: Seeing the Invisible*, September 27, 2007, http://nanoarte.blogspot.com/2007/09/alessandro-scali-robin-goodes-nanoart.html; *Three Drops (Short Version)*, 2008, http://www.youtube.com/watch?v=AmiSNUKn9Tg&feature=youtube_gdata_player; John Curtin Gallery, "Art in the Age of Nanotechnology" (Art Exhibition presented at the A Perth International Arts Festival exhibition, Perth, Australia, April 5, 2010), http://johncurtingallery.curtin.edu.au/exhibitions/archive/2010.cfm#nano.

[106] Suzanne Lacy, *Mapping the terrain : new genre public art* (Seattle, Wash.: Bay Press, 1995). Lacy has argued that artists who see themselves as mediators of public change through public art have been marginalized by traditional art critics (20). The establishment critics value only art that "subordinates function to craft" (21).

same way previous artists have commented on already-ubiquitous technologies, then they will make nano become more pervasive and important. They are not just portending the future, but hoping to create it.

In addition, *NANO, Science as Art, NanoArt* and *Sites Unseen* are examples of types of informal science education which attempt to investigate art and science practices as a means of creating educational experiences focused on nanotechnology. Educational experiences, in these examples, do not ensure that viewers or visitors can recount how big a nanometer is, but rather that they begin to understand the significance that a technoscience like nano has in society, the range of possible values and perspectives which determine that significance, and how their perspective, values, and practices also contribute to that significance.

Each of these projects recognizes that its visiting publics have little context through which to understand the exhibit. Thus, the exhibit itself has the chance to teach the visitors new ways to see and interpret science. Each exhibit would like to portray new ways of seeing and interacting with the world, but they all recognize that visitors' unfamiliarity with the concepts of nanotechnology prompts the need for their exhibits to be situated, at least somewhat, inside of concepts or in relation to abilities that the publics already have. For example, rather than trying to tell visitors how forces act differently at the nanoscale than at the macroscale, Vesna's *NANO* translates the visitors' movements into feelings and responses that simulate those differences. In addition, *NANO* maintains a sophisticated online presence (as do the other exhibitions) that document the past work, and organize and promote future work. These websites provide viewers with context for the projects. The artists/organizers/educators are able to frame their projects as well as to provide them with an ongoing existence long after their physical presence ends. These two aspects of these exhibitions, context and ongoing existence, are important in understanding the role the Viz Lab played in the NISE Network.

Science as Art addresses context in a different way. Instead of trying to use the images as a way to explain materials science, the organizers favor what they deem to be artistic images that resemble macroscale items like flowers, paintings, or foods. Designating these images as art demonstrates the MRS's belief that images of nanotechnology classified as art are a more effective way to interest viewers who (the MRS assumes) could not easily understand the science. The Society desires to stimulate the public to continue supporting nano, even if the public does not understand nano, by showing the public "aesthetically pleasing" portrayals of nanotechnology. By revealing to people that materials science manipulates matter at such small scales and is able to make images recognizable from the macro-world, *Science as Art* leads the public to acknowledge nano's future possibilities and their role in creating those possibilities. Nano, *Science as Art,* seems to tell its viewers, is worth funding because it has quasi-magical attributes. It looks like something we know, but is completely different.

NANO and the *NanoArt* movement more directly confront the possible outcomes for science in society if nonexperts are included in scientific knowledge production. Both exhibition creators talk about including their visitors in the knowledge-making process, as if their exhibitions are merely one part of an array of activities that create nanotechnology's role in culture. How the public produces those outcomes is less clear, however. In both exhibitions, the artists/organizers/educators support an educational model where learning can happen without knowing all "the facts." In *NANO,* rather than focusing on the nanoscale as an important concept worth trying to teach, the exhibition tries to allow visitors to understand why scale matters by helping them to feel how objects behave differently at a different scale. Visitors don't have to be able to conceptualize the size of nanoscale objects to begin to imagine how the differences in movement they experience could affect how materials interact.

Knowledge creation can occur simultaneously with learning, but what is knowledge creation or learning for these practitioners? In these models, publics do not have to participate in a citizen's school of science or serve as members of a deliberative forum to begin to learn how nanotechnologies are significant in their lives and to consider how they may want those technologies to be used. For these artists, learning is publics, or non-scientists, interacting with and interested in alternative (artistic) portrayals of an emerging technology. Learning about nanotechnology's potential possibilities symbolized by its portrayals in art both is and creates knowledge.

Transition: What is the relationship of these exhibitions to the NISE Network?

I attended a conference at the University of Buffalo in the late spring of 2009 called "Nanosensing." The objective of the workshop was to invite scientists, artists, historians, and educators who had experience with creating exhibitions for science museums and centers to attempt to design an exhibition on nanotechnology. Victoria Vesna, the creator of *NANO,* was one of the invited participants who gave a presentation at this workshop. She described her philosophies of learning about art and nanotechnology, many of which are articulated in the *NANO* catalog discussed above. At the meeting in Buffalo, she described having been invited to an early NISE Net planning meeting in 2005 where organizers were trying to decide what to focus their efforts on in terms of art and science collaborations. Vesna recounted that she vehemently opposed a focus on scale. In her mind, though scale was not entirely irrelevant, it should not be the primary learning objective for an exhibition on nanotechnology. According to Vesna, since nanotechnology holds far-reaching implications for society's development, the focus of art/science collaborations should be in the direction of nanotechnologies' potentially powerful role in society, with scale being just a secondary characteristic of that role.

At the time, Vesna knew I was studying the NISE Net, but she did not know I was specifically focusing on her work to compare it to the *Science as Art* and *NanoArt* exhibitions. At some point during our discussions a workshop participant showed a picture of one of *NanoArt*'s 2008 winners, Chris Robinson. Vesna scoffed at this image and enthusiastically exclaimed, "And *that* counts as art?" She implied that the digital media of exhibitions like *Science as Art* and *NanoArt* do not provide the immersive experience that allows for ongoing artist/viewer creations, and that this lack of immersive experience disqualifies such exhibitions as legitimate scientific-educational "art." I disagree with Vesna's position. I would argue that these two exhibitions do not include viewers in immersive visual experiences because that is not their goal. They do, however, attempt to teach people about the world (and the nanoworld) through artistic portrayals.

Thus, I present these four examples as representative of nanoart precisely because they vary so much from each other in form and purpose. Vesna suggested that she doesn't even consider *NanoArt* to be art, and perhaps according to her definition of art as immersive experiences where participants as well as designers continually combine their actions and thoughts to create new thoughts and reactions, it isn't. But clearly, if only proven by the institutional support of organizations like the MRS, the EuroForum,[107] and the University of Wisconsin's MRSEC, other institutions and practitioners believe these non-immersive art projects can serve as significant instances of science education. In addition, although the execution may be different, Vesna and promoters like Cris Orfescu share similar goals and beliefs about why to engage with the public about an emerging technology through art practice. Comparing how these examples represent types of art and nano educational philosophies, we can better understand what was lost when the NISE Network chose not to validate artistic methods as valid science education.

Vesna hopes that her work is not just interactive, but immersive. She tries to create experiences where visitors become part of a world to which they usually have no access. She is also well-funded and has the support of both the media arts community to which she belongs and at least a portion of the science community

[107] "Euroforum 2004 - Events - Resources - TakingITGlobal," accessed September 12, 2012, http://events.tigweb.org/4295. "The EUROFORUM is a unique model conference on the European Union. The conference utilizes different components of the EU's decision-making bodies to help with the future of the EU. This conference incorporates new components each year and is expanding their work discussing different topics from the EU's agenda. Sessions will be assembled to be held in English and in French. When the studies of all these committees will have been finished, resolutions and final communiqués will be submitted to the real decision-making bodies of the EU."

(James Gimzewski and the chemistry department at UCLA). Her work is also large scale; rather than printing what is small on bits of canvases, she designs entire worlds where, at least briefly, visitors can explore, experience, and create without consequence. Her work occurs through the collaboration of experts from the arts and sciences, but also from architecture and the humanities.[108] Arguably, it represents a supposed "third culture" that appears when successful collaboration occurs between like-minded scientists and artists.[109] Many of these characteristics are important to keep in mind when trying to understand the differences between the uptake of Vesna's work (it has been exhibited at a long list of science and art institutions including the Exploratorium) and the lack of uptake of the Visualization Laboratory's work. The idea that successful collaborations between scientists and artists create an altogether new form of knowledge was echoed by managers of the Exploratorium's artist-in-residence program like Pam Winfrey, as we will see in the next section. However, collaborations between art and science or between artists and scientists with the objective of creating new knowledge did not become a priority of the NISE Network's practitioners.

The Visualization Laboratory and an Obsession with Scale.

During the summer of 2008, I took a preliminary research trip to San Francisco's Exploratorium to confirm the possibility of doing participant-observation

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108 Katherine Hayles collaborated with Vesna on *NANO*, producing a book about the exhibit and concepts.

109 Ron Jones, "The New Age of Wonder: How Will We Pioneer Interdisciplinarity Between Design, Art and Science?," *Unpublished Manuscript* (2012).

with the Exploratorium's NISE Network staff, especially the Visualization Laboratory (Viz Lab), the following spring and summer.

On the day of my arrival at the Exploratorium, Diane Burk, an artist who was a member of the Viz Lab and whom I had met at a conference on nanoimages in previous years, brought me inside the main building where I was going to attend the Viz Lab's weekly group meeting. At the meeting, I conferred with the project manager about the possibility of visiting for an extended stay. She explained that she had been trying to scrounge together documentation of the *ArtNano* artist-in-residence events that the Exploratorium had hosted the previous year. She exclaimed exasperatedly that no pictures had been taken and no interviews conducted. There had been little to no documentation of the events. She mentioned that she had tried requesting that the artists send some sort of representation of their experience to her, but after the fact she was finding them hesitant or unable to do this. I learned later that the Exploratorium owns "the artifacts" and the artists own the "ideas" which are the results of the artist-in-residence collaborations. In this case, the Exploratorium had in its possession neither the artifacts nor any documentation of the experiences; therefore, it had difficulty putting together an online exhibition presence, like those of the four vignettes that I use for comparison in this chapter.

During this trip to the Viz Lab, I learned that the name "Viz Lab" merely described ideal working conditions that did not exist. There was no actual space for the members to share while working. In fact, it was repeated to me on multiple occasions that there was very little extra space to be found in the entire institution.[110] Also, the label "laboratory" did not really describe the working practices of this group, much to their frustration.[111] Most individuals had offices of their own not shared with anyone, or shared with other artists or designers who were not part of the Viz Lab. As far as I could tell, other than the evaluators, none of the individual Viz Lab members shared space with one another. This is not to say that they didn't collaborate; it was clear that at least the artist members often thought, worked, and experimented together. The rest of the Viz Lab, however, seemed to be assigned to separate tasks of the larger project which they worked on individually. I found this unexpected since in the NSF project descriptions and annual reports, the Viz Lab was described as a group of people who were collaborating to address problems associated with using nanoimages to teach their publics about nanotechnologies; in reality the members worked more like a production house, with little input into what the content of the production should look like. The only way in which I could tell that they resembled a laboratory was that they had group meetings.

After the initial group meeting and during subsequent conversations with other members of the Viz Lab team, I learned that none of them had actually been working on the NISE project when the artist residencies, which I had read about in the NSF files and online, occurred; hence the lack of documentation of their work. Six months prior to my visit, the team had been assigned to produce a "scale ladder" in addition to

[110] Of course this may have just been an indirect attempt to let me know there was no room for *me*, as I was eventually informed.

[111] Burk, "Visualization Laboratory Group Meeting."

making three illustrations about scale in which a butterfly, a computer chip, and a human body were represented from the atomic level to the macro level. Recently, one of their members had begun work on what they were describing as an image-database. This included some simple descriptions paired with a variety of images from nano-related science at various scales. These projects served as the main "products" of the Viz Lab's work.

As it turned out, I could not return to the Viz Lab to follow up on this initial visit. I therefore changed the focus of my dissertation research from the role images and art have (or have not) played in the NISE Network work to (for one part of the dissertation) how the Exploratorium, as an institutional expert on artist-scientist collaborations, determined which art-science educational modules could count as part of the NISE Network's corpus and, by extension, what type of art methods would be deemed appropriate science education for the field of ISE focused on nanotechnologies.

The Visualization Laboratory was originally promoted as one component of the larger "Center for NISE Research" which was to be housed at the Exploratorium under the direction of principal investigators Rob Semper and Tom Rockwell. The original purpose of the center was to "to focus on collection, coalescing, developing, and disseminating knowledge about how to effectively communicate nanoscale science and technology to the Network's target audiences."[112] The center was made up of five major areas: NISE Professional Resource Center, Visualization Lab, NISE

[112] Larry Bell et al., *Proposal to National Science Foundation* Proposal (Museum of Science, Boston, MA: National Science Foundation, April 6, 2005), 11.

Public Website, professional development for ISE and Nanoscale research educators, and NISE Research and Evaluation.

When I arrived at the Exploratorium in 2008 there was no longer a "Center for NISE Research." Instead, there was only the group of researchers described as the Viz Lab.[113] From the network's perspective by 2008, the majority of the work that was contributed by the Exploratorium was the work of the Visualization Laboratory.

During the first four years of the NISE network, the Viz Lab documented the production of the following deliverables:[114]

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[113] Also at the Exploratorium in 2008 there were a handful of people who served as evaluators for Viz Lab research, a woman coordinating with four other NISE Net partner museums on NanoForums, and another coordinator for the annual NISE Net meeting. Between the summer of 2008 and 2009, the official NISE Net website was transferred to the Science Museum of Minnesota. By the summer of 2009, when I arrived at the Science Museum of Minnesota (SMM), Research and Evaluation had also been moved away from the Exploratorium and was being shared by SMM and the Boston Museum of Science (MOS). In addition, the proposed public website had been abandoned. A website for ISE practitioners had recently begun to be promoted as a valuable resource for NISE Net organizers and those interested in nanotechnology informal education, however. A handful of individuals from institutions throughout the United States led the regional workshops, the major professional development activity of the NISE Net in those years, but no one from the Exploratorium took part. In effect, after two years, the Exploratorium no longer had responsibility for major portions of the programming and administrative work of the NISE Net, despite having been the original site for that work. The Network determined that other sites could better serve the network and attend to these goals than the Exploratorium.

[114] Like all NISE Network products, the scale ladders are used by permission under Creative Commons. They were "developed for the NISE Network with funding from the National Science Foundation under Award Numbers 0532536 and 0940143. Any opinions, findings, and conclusions or recommendations expressed in this product are those of the authors and do not necessarily reflect the views of the Foundation." The owning institution is the Exploratorium. See the following web address for more information: http://www.nisenet.org/catalog/media/scale_ladder

1. Scale Ladder (Zooms and diagrams)

2. Image Database (Image Collection)

3. Artist Residencies (ArtNano and Simulations)

4. Illustrated Zooms (Illustrations) and Physical Models (Nanoscape). [115]

That summer when I visited the Exploratorium the Viz lab staff whom I met had only been working concertedly, they said, for about 6 months. Since then, their work had concentrated on the creation of what they called a "zoom." This was an interactive computer-based illustration that allowed viewers to move from macroscale objects to the nanoscale, much like the Morrisons' *Powers of Ten*. [116]

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[115] "Visualization Laboratory | NISE Network," accessed September 10, 2012, http://www.nisenet.org/viz_lab.
I do not have data that allows me to confirm details of the Exploratorium's role. Off the record, members of the NISE Network who were not employees of the Exploratorium told me they believed that it had received approximately one third of the funds allocated to the NISE Network. According to the members of the Viz Lab, the funds they received from NISE Net supported the Exploratorium's work on these four "deliverables." Unfortunately, the off-the-record comments made to me suggested, it was unclear to the other members of the NISE Net what work the Exploratorium was, in fact, contributing. These members were aware of what work had been reassigned to their institutions (website maintenance, evaluations, professional development), but most of them had to struggle to explain to me the contributions the Exploratorium made to the Network as a whole (especially given that many of them had been assigned to the work that had been moved from the Exploratorium).

[116] C. Heath and D. vom Lehn, "Configuring 'Interactivity': Enhancing Engagement in Science Centres and Museums," *Social Studies of Science* 38, no. 1 (February 2008): 63–91, doi:10.1177/0306312707084152. Part of these authors' interests focus on the definition of interactivity as computer-based interactions.
While visiting the Viz Lab, members showed me the book by Philip Morrison, Phylis Morrison, and Office of Charles & Ray Eames, *Powers of Ten (Revised)*, (Scientific American Library, 1994).which was based on the movie by Ray Eames and Charles Eames, *Powers of Ten* documentary short film, 1968, http://www.powersof10.com/film.

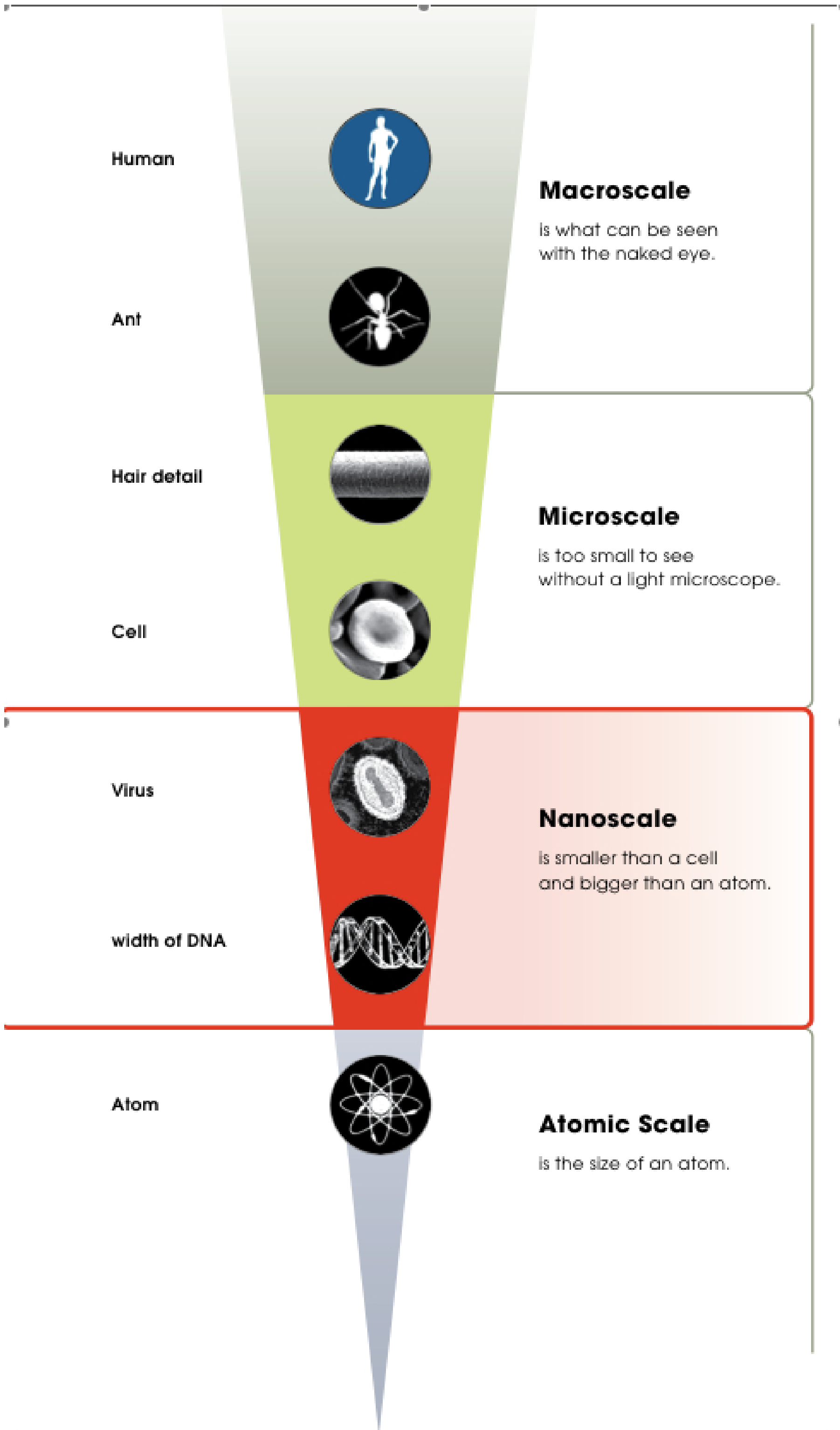

Figure 2.1 Traditional Zoom (or what comes to be called "Scale Ladder")

The two primary artists, who I will call Lewis and Karen, working on these illustrations expressed their frustration at what they called a problem with "oversight." The main artist, Karen, felt the most effective and visually striking zoom was oriented in a spiral (see Figure 2.2), but the Viz Lab had been asked by the NISE Net to produce a "traditional zoom" (see Figure 2.1), which apparently excluded spirals. As I talked with Karen and Lewis, they admitted that though the spiral zoom *was* more interesting to them, what they would *really* like to do is create a multidimensional whole-body experience, what they called "experiential interactivity."[117] This would be a three-dimensional imaging technology that could show people how to interact with images. They lamented that there was no support for these more complicated and resource-intensive projects.

What excited them most was the possibility of being able to acquire a lab space for the Viz Lab where they could develop 3D imaging technology. They wanted to work on something that could "exist somewhere between the stated goals of the bureaucracy and experiential interactivity." They became very excited at the possibility of creating a tool that could show people how to interact with images, which could show an uninitiated user how to interact through changes in color dimensions, process, and other details. However, the artists expressed some frustration at their inability to get support for these approaches from the Network. Lewis said that the NISE Network approach was problematic because… "(1). It's a network and the museums have never done that before and (2). It's about NANO, a topic these

[117] Burk, "Visualization Laboratory Group Meeting."

designers and curators are unfamiliar with. “Why not gravity?” he asked. That’s a topic they'd be more comfortable with.” The Project Manager of the Viz Lab, they said, told them that the NISE Network needed a “scale ladder,” so that is what they were trying to create. Developing a spiral zoom was their incremental attempt to do work addressing some of the issues they were most excited by.

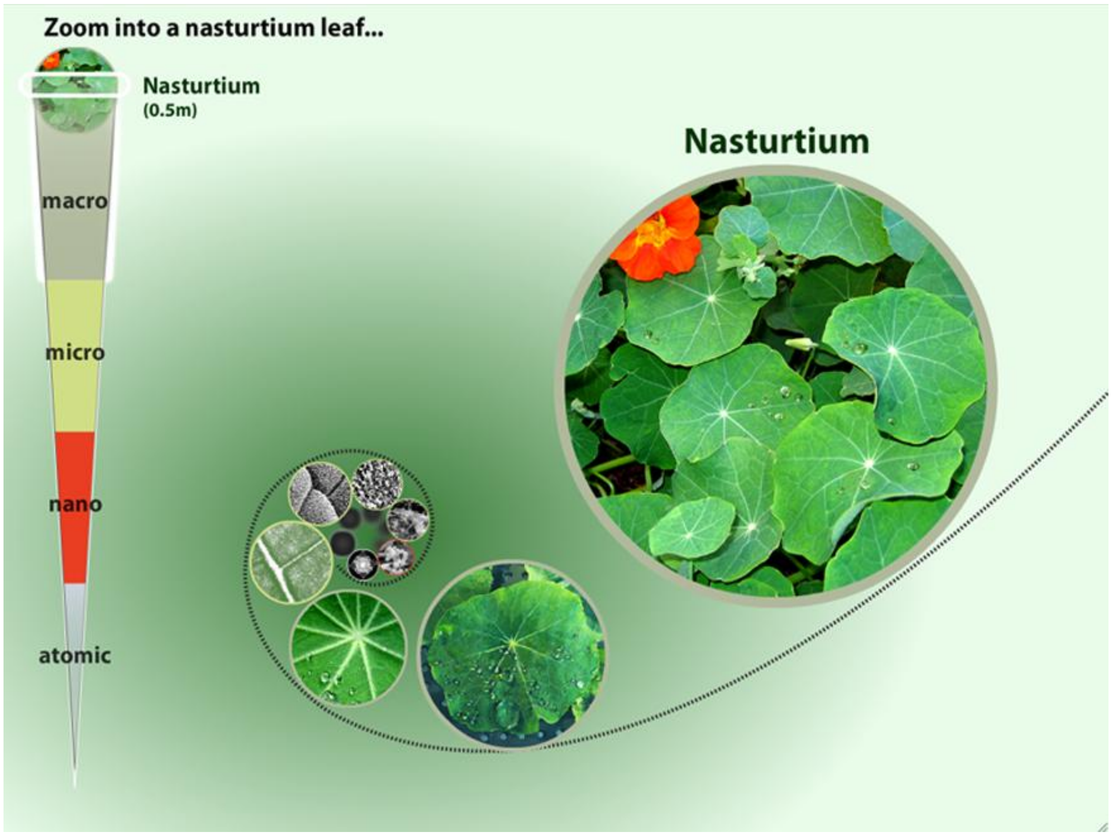

Figure 2.2 Spiral Zoom (which also includes a scale ladder)

The original idea for the spiral zoom came from an artist who had been invited to do an artist residency as part of the Exploratorium’s *ArtNano* program. Santiago Ortiz is a Colombian-born professor of art and technology at the University of Madrid. He spent much of his two weeks at the Exploratorium developing sketches for Flash prototypes like the one below (Figure 2.3).

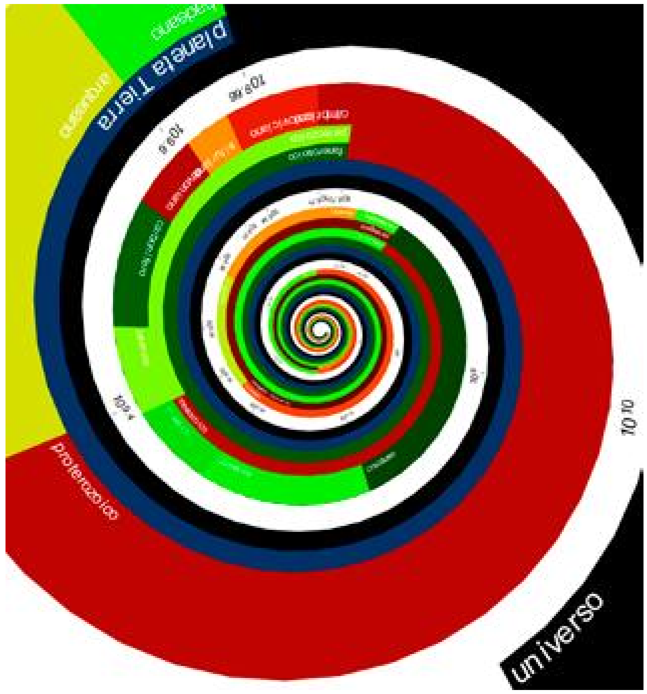

Figure 2.3 ***Spiral del Tiempo (Time Spiral)*** **(2005)**

The idea of representing scale in a nonlinear form appealed to the other artists and designers at the Exploratorium. In addition, Ortiz's medium (Flash) was something they had access to and experience with. Lack of access to immersive visual experiences seemed to be a factor limiting the continuation of many of the artist residencies. Rather than supporting artists in their creation of immersive experiences at the Exploratorium, the museum invited artists Scott Snibbe and Victoria Vesna to present immersive art which they had produced for other forums.

Since 1974, the Exploratorium has invited artists to come to the institution to collaborate with the in-house staff, technologists, and other creators. The artists receive a stipend, plus living, food, and travel expenses. Generally, the Exploratorium first invites artists to come to the museum for a short trial residency. This lasts from a few days to two weeks. This short stay or as Exploratorium senior artist Pam Winfrey called it, the "small experimental event," allows the institution and artist to decide if a longer residency would be worthwhile.[118]

When Peter Richards began the Exploratorium's artist-in-residence program, it was focused on exhibit creation and natural phenomena. In the mid-1980s, the focus was expanded to think more about the roles that film and other experimental art forms like poetry, theatre, dance, and music could play in the creative process. As of 2010, the space of the Exploratorium was divided into seven separate exhibit and content areas with each area having a curator and associate curator assigned to it. Each of these spaces includes an art component.[119]

The Exploratorium's policy is to recruit artists whose work is relevant to the thematic concerns of the museum. This policy states that all artifacts which are a result of the residency thereafter belong to the museum, but the idea which prompted the artifact belongs to the artist. In practice, with something like a choreographed ensemble dance, the Exploratorium is credited with "development," but the piece itself can be reproduced elsewhere.[120] Pam Winfrey told me that the Exploratorium's lawyers tend to roll their eyes at this policy, but nonetheless it has worked for the museum.[121]

I was particularly interested in what Winfrey saw as the purpose of these residencies. Why are they so important to the Exploratorium's identity, especially

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[118] Pamela Winfrey, "Interview by Author with Artist from Exploratorium" Skype, Spring 2011.
[119] Ibid.
[120] Ibid.
[121] Winfrey reflected that this reaction is probably in part because if push came to shove it would be difficult to separate the idea from the artifact.

when, as she told me, the collaborations are not necessarily focused on an exhibit that their visitors will experience? Winfrey said that "a lot of the value of the residency is not [associated with] the object, but [with] the development of the idea. Anything that adds to the creative agar of the place" is seen as a productive and valuable experience.

Winfrey reported that when putting together a show on memory, the Exploratorium invited an artist who created a "monstrous, mechanical thing, which failed [to work]." The object was a "maintenance nightmare," but Winfrey told me that if you asked the collaborators whether that particular artist residency was a failure, they would say: "In terms of the object? Yes. It was a complete failure. But, in terms of the process? No." Apparently the in-house staff at the Exploratorium learned a great deal about pneumatics and felt that the interactions with this artist were valuable because they could take this knowledge and apply it later. This was not totally unlike the Viz Lab's desired use of Santiago Ortiz's spiral zoom. The Lab tried to take the knowledge and experiences they had learned from his residency and demonstrate them through the Spiral Scale ladder (Figure 2.2). Unfortunately, the spiral was not the preferred scale ladder of the NISE Network.

According to Peter Richards, the founder of the Exploratorium's Artist-in-Residence program, "through an evolutionary process, a culture has emerged [at the Exploratorium] that nurtures playful investigation, experimentation, and a propensity for taking risks." It was this "propensity for taking risks" that seemed to be lacking from the Exploratorium's work for the NISE Network. The NISE Network sponsored a half dozen of these residencies as part of its mission to learn how to best present difficult-to-understand concepts of the nanoscale to their visiting publics.

Nevertheless, no attempt was made to demonstrate that knowledge through distributed deliverables. The deliverables, particularly the "traditional zoom," did not rely on or build from the knowledge learned or produced during the artist-residencies.

The Exploratorium's Viz Lab eventually produced an online document called *ArtNano*, which described the artist residencies. This document reads like an exhibition catalog and describes *ArtNano* and the associated residencies as if they were part of one concerted set of exhibitions on nanotechnology. In this document, it is unclear which of these artists took part in what Winfrey described as the "traditional" artist residency. When I asked, I was told that of the artists who were invited to be residents, only Santiago Ortiz and Eric Heller were invited specifically as part of the Exploratorium's nanotechnology work. Stephanie Maxwell, another artist featured in the *ArtNan*o catalog, was invited by the film group and happened to be at the Exploratorium at the same time as Heller, thus leading to her interest in nanotechnology. The other artists and work described in *ArtNano* were commissioned by NISE Net, but did not participate in the artist residency program. Scott Snibbe was well known for his "immersive interactive art," prompting the Exploratorium to commission his "Three Drops" in 2006 as part of their NISE Net contribution. Victoria Vesna had previously produced "Nanomandala" and "Zero@wavefunction" (2002) for other spaces, and the Exploratorium asked her to present "Nanomandala" during the first annual NISE meeting in San Francisco in 2005. In 2006, "Zero@wavefunction" was one of two parts of an Exploratorium exhibition titled "In the Land of Lilliputians," although "Zero@wavefunction" was actually a recycling of the buckyball portion of *NANO*. "Zero@wavefunction" was paired with *100*

Nanowebbers, an interpretive video by the pair of artists known as Semiconductor. *100 Nanowebbers*, which the *ArtNano* archive describes as "a set of moving images which reveal the moving world in flux," was another art project rented by the Exploratorium.

In other words, only about half of the residencies now mentioned on the *ArtNano* website, which eventually came to document the *ArtNano* project, were artist residencies in the traditional sense. The rest, though they are described as residencies, were not. Instead, the artist was invited as part of another program, or the Exploratorium commissioned a piece by the artist (as in the case of Snibbe and Vesna). Nevertheless, the online documentation presents all of the residencies as having been part of the *ArtNano* program.

Whereas Winfrey described successful residencies as being valuable to the "creative agar" of the development process, the majority of these artists who presented as part of *ArtNano* did not contribute to that agar, and their participation was only valued insofar as they had an object to present on the floor at the Exploratorium.[122] Although the NISE Net collaborators thought the Viz Lab was engaging in artist-residencies to produce knowledge informing art practices for the network, and in spite of the amount of time and resources devoted to these residencies in the NSF

[122] Interestingly, the associate project manager of the Viz Lab claimed that his Exploratorium colleagues harbored resentment toward the Viz Lab because there was an impression that it was well-funded, but never exhibited anything on the floor. The associate project manager argued that this created a sense that their colleagues thought they were getting paid to do nothing. I found this particularly interesting given that Winfrey recounted that frequently the artist residencies did not result in exhibits on the floor.

correspondence, the Viz Lab's main concentration was not the residencies at all. The *ArtNano* project, which is presented by the NISE Network as being one of the primary educational projects pursued by the Viz Lab, appears to be more of a cobbled-together set of brief visits and found artworks, of which very little knowledge translated to the network at large.

The artists themselves also were not altogether clear about the value or purpose of their work for the Exploratorium. The case of artist-scientist Eric Heller is instructive in this regard. Heller is a physicist at Harvard University, and by the late 2000s, he had been presenting images from his research as art for close to a decade. Heller told me that he came to the Exploratorium for only a few days. He felt that "our visit was more informal and the support given to us had to be fought for once we were there. In the end, though, the support was very good."[123] He and Don Eigler, the maker of one of the most famous nanoimages, the quantum corral, "set up a ceiling wave tank which projected pool bottom caustics to the floor, which looked 3D with stereo glasses on.… Everybody who saw it loved it, but not many did – it had to be removed soon after our visit, and it was not scaled up to a regular exhibit."[124]

Pam Winfrey called Heller's experience an "internal experimental residency," which suggests that the staff at the Exploratorium were not expecting many people to see his and Eigler's work. Winfrey seemed to think Heller's time had in fact been fruitful, as she reported that many of the exhibition developers had spent time with

[123] Eric Heller, "Interview by Author with Physicist from Harvard University" Email, Spring 2011.
[124] Ibid.

him, even though he was only at the institution for a short time. Heller, however, felt under-appreciated. He seemed to believe that he had been invited to the Exploratorium to share his scientific expertise (even though he was invited as an artist) and that his expertise was more valuable than that of the other artists (e.g. Stephanie Maxwell) who had also been doing a residency at the same time as Heller. Heller attributed this misuse of “resources” to “the director’s” (he was not clear about which one) professional background as an artist. As he put it to me:

> The management staff did not seem to appreciate the level of scientist that they had visiting. Eigler is famous, and I am a member of the National Academy, etc. etc. We could have been used much more effectively. We were given…time and attention…equal to [that of] artists who knew less than nothing about nanotechnology – who made weird, personal impressions of it. Now, this is fine for an art museum, but this was a science museum. The director had an art background, however, which may explain the outcome.[125]

Heller’s comments, especially contrasted with Pam Winfrey’s thoughts, begin to illustrate some of the pedagogical conflicts and disciplinary allegiances which led to the Exploratorium playing less of a role in the NISE Net than the NISE organizers had at first assumed. In particular, he demonstrates how science education is frequently thought possible only if produced by and in relation to scientific expertise. If the exhibits seem “weird” and “personal,” they must not be able to produce valuable learning about science.

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[125] Ibid.

I asked Winfrey why she thought art has played such a small role in the NISE Network. "First things first, so art gets cut," she said. In her experience with science education, she said, scientists and those who see their first allegiance as being to science forget sometimes that people need to learn why they should care. She argued that artists could have been a valuable addition to the NISE Net because artists focus on making meaning. Also, artists recognize that visitors have to be taught why things are important and why they should care about them. Artists cannot assume that the visitors will find something meaningful just because artists find it meaningful. Winfrey believes this was the mistake of the NISE Net. She has been happy to find that the people who work at the Exploratorium are dedicated to and have seen how "multidisciplinary ways of working are successful." Art and science have an equal partnership, she said; art, therefore, is not in the service of science.

A few weeks before I spoke with Winfrey, the Exploratorium had hosted a conference focused on the theme "Art as a Way of Knowing."[126] At the conference, speakers or "thinkers," as she described them, examined different ways that art enters the science education discussion. They were particularly focused on the differences in the value systems of art and science. There were of course structural reasons that the work of the Exploratorium did not play a large role in the NISE Net, but Winfrey's and Heller's comments reflect more deeply situated educational commitments, which might have predicted the failure of art to take hold in the NISE Network from the beginning. More specifically, the scientific community of which the field of informal

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[126] "Art as a Way of Knowing Conference | Exploratorium," accessed September 10, 2012, http://www.exploratorium.edu/knowing/index.html.

science education is a part has difficulty validating knowledge created outside traditional laboratory and field research settings as valid scientific knowledge. The lack of consensus over the definition of nanotechnology referred to in Chapter 1 makes this difficulty even more evident.

Winfrey was not the only person to highlight the question, "what are people really learning?" This was a theme that ran throughout the NISE Network evaluations of programs. Again Winfrey:

> I think particularly with the nano thing, the scientists are grappling with the same things that other people grapple with. Language really lags what's really going on down there. All of those things really position artists to uniquely equip us and help us imagine that landscape.[127]

"Imagin[ing] that landscape" might be the exact problem. As educators of the NISE Network have tried to do so, they have moved away from valuing art practices as a way to access that which is admittedly difficult to articulate, even for scientists. When, in an early meeting of the Network Executive Group, it was decided that scale was a priority, the NISE Network effectively deemed other educational methods ineffective or, worse, irrelevant to their work.[128]

As I document in the following chapter, the NSF's and some educators' dedication to a quantifiable, determined way of thinking and learning, led to a preference for easily (and quantifiably) evaluated programming modules. This was yet another reason that art exhibits and practices did not take hold in the NISE Net. At

[127] Winfrey, "Interview by Author with Artist from Exploratorium."
[128] Burk, "Visualization Laboratory Group Meeting."

the same time, a number of internal, institutional issues made large contributions in reducing the role the Exploratorium played in the NISE Network overall. Comparing *ArtNano* to *NanoDays* (Chapter 3) and *NanoForums* (Chapter 4) demonstrates not just the NISE Network's failure to value another possible educational model, but its determination that informal science education about emerging technologies must prioritize so-called scientific facts over imagination. That determination closed down an avenue through which science could have been democratized.

The artist-educators of the Exploratorium like Pam Winfrey attempted to break down the dichotomy, often relied upon in science museums, that separates the visiting publics from experts. But the NISE Network and the NSF are joined in a "cooperative agreement" for this grant. Therefore, the NISE Network must constantly respond to and include the NSF's critiques of how the Network pursues the outcomes and goals stated in the original proposal. Due to the epistemological allegiance to educational objectives not compatible with open-ended systems of learning as evidenced by perspectives like Heller's or the choice to use the "Traditional Zoom" instead of the "Spiral Zoom," art failed to take hold as part of the larger NISE Network. Ironically, this meant that the art and art methods that were deemed "acceptable" to the Network planners turned out to fall flat with the Network as a whole. The knowledge that was created by *ArtNano* and the Viz Lab could not find a foothold in the Network at large.

The role of the public in shaping scientific and technological outcomes has been a much-debated topic for scholars, museum educators, and policy professionals. Authors have written about science-fictional imaginations of the potential of nanotechnology for decades, while theorists' proposals about its potential have continued in the shadow of the human genome project and genetically modified foods. Scholars have worried about nanotechnology's ethical, legal, and social implications; through funding by government bodies like the National Science Foundation, they have been able to study and understand what the public knows and believes about nanotechnology and its regulation. However, little research beyond that of scholars analyzing the media has asked why the public has formed the opinions it has or who has tried to shape those opinions and through what methods.[129]

If scientists and the government have historically possessed the ability to limit the negative effects of new science and technology, they have nevertheless failed to do so (as evidenced by developments in atomic energy, combustion technologies, and food processing, for example). Although there may not be any reason to believe that scientists and policymakers are inherently incapable of playing the role of regulators, they have frequently failed at this job. Therefore, the artists and educators featured in this study believe that only through the power of public knowledge can

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[129] For some examples which try to go beyond these limits see: Greg Myers, *Writing Biology: Texts in the Social Construction of Scientific Knowledge* (University of Wisconsin Press, 1990); Thurs, "Tiny Tech, Transcendent Tech Nanotechnology, Science Fiction, and the Limits of Modern Science Talk"; Milburn, *Nanovision*; David M Berube, *Nano-Hype: The Truth Behind the Nanotechnology Buzz* (Amherst, N.Y: Prometheus Books, 2006); Davis Baird, Alfred Nordmann, and Joachim Schummer, *Discovering the Nanoscale* (Amsterdam: IOS Press, 2004), http://www.ifs.tu-darmstadt.de/fileadmin/phil/nano/toc.html; Chul-joo Lee, Dietram A. Scheufele, and Bruce V. Lewenstein, "Public Attitudes Toward Emerging Technologies: Examining the Interactive Effects of Cognitions and Affect on Public Attitudes Toward Nanotechnology," *Science Communication* 27, no. 2 (December 1, 2005): 240–267, doi:10.1177/1075547005281474; Dietram Scheufele and Bruce Lewenstein, "The Public and Nanotechnology: How Citizens Make Sense of Emerging Technologies," *Journal of Nanoparticle Research* 7, no. 6 (December 1, 2005): 659–667, doi:10.1007/s11051-005-7526-2; Matthew Nisbet and Dietram Scheufele, "The Future of Public Engagement," *The Scientist* 21, no. 10 (2007): 38.

nanotechnology's potential be safely shaped. This is true for the Viz Lab as well as for the four other nanoart exemplars.

These vignettes are evidence of a larger pattern of nanoartists creating, promoting, and organizing nanoart because they believe, contrary to many artistic traditions, that publics can and must participate in shaping what nanotechnology becomes, whom it affects, and how it is used. These artists believe that publics should participate in shaping nano and that, contrary to modernist artistic traditions that often discourage artists from using their art in the service of social change or other ulterior goals, they, the nano-artists, can and should use their art to impact society. Perhaps this broader definition of education, the recognition by non-expert publics of the potential roles a science can play in society, reflects a philosophy of learning that only artists could have. Certainly historically, informal science education institutions have not been a place to foster deliberative dialogue,[130] even if they have succeeded in producing learning, excitement, and awe. Until recently, as I document in Chapter 4, ISE institutions have not seen themselves as obliged or able to empower their visiting

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[130] Larry Bell, "Interview by Author with Co-principal Investigator of NISE Network" digital recording device, November 30, 2009.
See, Hein, *The Exploratorium*.
Hein argues in her history of the Exploratorium that activism was exactly the reason the Oppenheimers were interested in informal science education. She goes on to say, however, that the philosophy of engagement whereby citizens learn about their daily world and the possibilities of their involvement in it were lost when practitioners cherry-picked exhibitions from the Exploratorium's cookbooks.

publics to have a voice in determining beliefs about how, when, and by whom science is used, much less how science is valued.[131]

What do these artists teach, if their methods *and* their goals vary so substantially from informal science educators' traditional definitions of learning? When little content about nanotechnology's physical or chemical characteristics is learned, but viewers and visitors become aware of nanotechnology in society and possibly aware of their potential power to define this new technology, has art successfully educated? The answer depends on whether successful, institutionally supported education can provide more questions than answers, stimulating critique as well as awe. More importantly, if education acknowledges that there are many possible futures as well as many possible histories, then these artists can redefine not just what counts as nanoart or nanoscience, but what counts as valid knowledge about the roles both play in society. The open-endedness of these art exhibits is a significant reason why the exhibitions seemed successful to their designers. They did not care whether visitors walked away able to conceptualize the nanoscale. Instead, the goal of these exhibits was to raise public awareness of other versions of science in hopes of helping viewers and visitors to play a role in how nanotechnologies are used in the future.

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[131] Aquariums and zoos have long been sites of informal education which were exceptions to this. One of their primary purposes was to enroll visitors in the political debates which promote conservation and awareness of the role humans play in the environment, globally and locally. See John Howard Falk et al., *Why Zoos & Aquariums Matter: Assessing the Impact of a Visit to a Zoo Or Aquarium* (Silver Spring, MD: Association of Zoos & Aquariums, 2007).

These art exhibitions are important because they represent nanotechnology's growing cultural presence. These exhibitions were not just one-offs. They represent the beginning of a sustained focus on technology that is historically and culturally significant. Portions of *Nano* were exhibited later by the Exploratorium as well as by numerous other museums. MRS has continued to sponsor *Science as Art* bi-annually. In 2012, as this thesis was being completed, Cris Orfescu completed the 4th annual *NanoArt* competition, and *Sites Unseen* was exhibited at the Madison airport as well as at two other venues after the initial show. None of these exhibitions has been formally evaluated, however. Their learning outcomes and goals are not easily quantifiable. The sponsors of the exhibits have not been focused on what content publics learn about nanotechnology, but rather on how art and artists give form and meaning to abstract concepts. Scientists themselves struggle to find the language to discuss nanotechnologies with one another; thus, educators are left with the dilemma of watering down the science to such a degree that their descriptions become meaningless, or valuing the ability of practitioners who work in metaphors to demonstrate knowledge through ways that are not, at first, obviously discursive.

Conclusion

ArtNano was one of the three primary foci of the NISE Network's programming efforts. However, it failed to take hold in the Network at large. That failure represents the limitation of the model of informal science education that NISE Net staff believed NSF was promoting. ArtNano serves as a good example of ISE practices that were not counted as the "right" kind of science education, but seem to have obvious educational merit.

The institutional organization of the Exploratorium served as a barrier to including art practice in the distributed science educational modules. In particular, because the Exploratorium was seen as the field's expert on art and visualization practices for science education, there was little attempt to form an art-science working group which included representatives from other institutions besides the Exploratorium. This lack of collaboration also meant that individuals at the Exploratorium were less in touch with the differences in priorities and needs between their institution and other ISE institutions.[132] Paul Martin, a Vice President of the Science Museum of Minnesota and a PI of the NISE Network, told me that at the beginning of the grant, the PIs had thought that each of the lead institutions would be in charge of its areas of expertise for the Network, and each would simply take its third of the money, use it to do what it wanted, and then distribute whatever it created to the rest of the member institutions. Early in the grant, the Network Executive Group realized that this was not the model they wished to follow; instead, they preferred a more collaborative approach.

However, the shift in operational mode did not reach the Visualization Laboratory; it was directed according to the original, distributed model. As such, there was little or no dialogue between the members of the Viz Lab and the other leading members of the NISE Network, leading the Viz Lab's work to never find a comfort zone between what the Network could use and what the Viz Lab members were willing or able to produce. Finally, the Exploratorium and the Visualization

[132] Anonymous, "Interview by Author with Co-principal Investigator of NISE Network" oral, 2009.

Laboratory itself were negotiating internal organizational issues which led to the lack of documentation of the artist-residencies and the lack of organization in regards to the project goals of the Viz Lab in general.

As I mentioned in Chapter 1, the informal science education field had a pre-NISE Network interest in attending to the challenges of presenting current research in ISE institutions. As part of this interest, there was a focus on more thorough evaluation of the educational products related to current science.[133] This dissertation does not try to assess whether the NSF took up this interest in improved evaluation in an attempt to follow ISE trends or if there were other reasons, apart from the interests of the field's leaders, to require evaluation in the cooperative agreement. Nevertheless, statistical evaluation became a crucial part of the cooperative agreement and the NISE Network. Teaching educators to conduct evaluation as well as teaching them to understand the use of evaluation became two important goals of the NISE Network, as I will show in Chapter 3. The evaluation team was headed by leaders in the ISE field and may have been the most consistently active working group of the NISE Network, since it was required to assess every major activity of the Network.

Formative and summative evaluations based on quantitative data are only one way to value and assess programming. In the NISE Network, however, these methods created some of the most important criteria by which to formulate those judgments. Even while the evaluations revealed their own limitations, as the following chapter

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[133] Graham Farmelo and Science Museum, *Here and Now : Contemporary Science and Technology in Museums and Science Centres : Proceedings of a Conference Held at the Science Museum, London, 21-23 November 1996* (London: Science Museum, 1997).

will explain, there was nevertheless an insistence by the NSF that the success of the programming should be judged by the results of the evaluations. This expectation heavily influenced the NISE Network's inability to include educational programming with more open-ended learning outcomes, as conflicting ideologies about what counts as worthwhile informal science education helped prevent the Network from using art methods to teach its publics about an emerging technology.

CHAPTER 3

NANODAYS: TABLE-TOP EXHIBITS AND THE TENSION BETWEEN PROMOTION AND EDUCATION

Introduction

In January of 2005, the National Science Foundation put out a solicitation detailing a new major initiative in informal science education. The provisions and objectives of what eventually came to be known as the NISE Network were outlined for the future award winners of this cooperative agreement. This document, which reflects numerous prior formal and informal meetings among informal science education (ISE) practitioners from institutions throughout the United States, sums up the "overarching program goals" of the Nanoscale Science and Engineering Education (NSEE) program. The NSEE solicited the NISE Network and the Nanotechnology Undergraduate Education (NUE) grants as two separate components of the NSEE program's attempt to achieve these overarching objectives.

> Its goals are to develop strong partnerships linking science educators with nanoscience and engineering researchers, and to increase knowledge of advances in nanoscale research and technology and their impact on society.[134]

Specifically, the NISE Network was meant to

> foster public awareness, engagement, and understanding of nanoscale science, engineering, and technology through establishment of a Network, a national infrastructure that links science museums and other

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[134] *Nanoscale Science and Engineering Education (NSEE) Program Solicitation*, Synopsis of Program Goals.

> informal science education organizations with nanoscale science and engineering research organizations.[135]

Eventually, the NISE Network grant was given to a coalition of science museums and centers scattered throughout the United States. In the Network's attempt to meet these goals of "awareness, engagement and understanding," the organizers of the NISE Network developed *NanoDays*, a set of distributable table-top exhibits whose content focused on conveying the basic principles of nanoscience.

According to Principal Investigator Larry Bell and *NanoDays* coordinator Rae Ostman, after a decision *not* to concentrate on full-scale exhibitions was made, the creation of *NanoDays* and the distribution of its associated "kits" were a means of meeting NSF expectations of dissemination and evaluation, while reflecting the ISE field's approach to emerging technology education.[136] The *NanoDays* Kits contained table-top exhibits, each of which explained a particular nanoscale phenomenon. Two of these exhibits, "Exploring Tools" and "Exploring Size," will be discussed in detail below. The kits include all the materials needed to put together each exhibit, as well as a guide which closely directs educators who will present the material. The guides include explanations of what to tell visitors to do with the materials, what visitors should understand about the phenomena observed or felt, and how those experiences relate to nanotechnology.

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[135] Ibid., [A] Nanoscale Informal Science Education.
[136] Rae Ostman, "Educational Programming and Regional Meeting Coordinator", August 2008; Larry Bell, "Interview by Author with Co-Principal Investigator of NISE Network," digital recording device, November 30, 2009.

The table-top programming was the best way the educators found to guarantee the use of the learning modules by the diverse group of museums, science, and research centers which made up the network. In 2011, the first year "Nano and Society" as a content area was addressed in *NanoDays*, there were eleven different kit-equipped modules. In 2008, the first year of *NanoDays*, there had already been ten modules, but only three of those still remained as part of *NanoDays* by 2011, thus indicating the rapid change in specific modules.

NanoDays is a week in the spring that the Network coordinated for every museum or science center receiving kits could highlight the table-top exhibits, ideally in coordination with other community outreach activities associated with nanotechnology. The NISE Network coordinators called this program *NanoDays* because each location, at least in theory, would highlight the table-top exhibits about nanotechnology on precisely the same days. Institutions sometimes created other programming activities to complement the *NanoDays* kits. Through these kits, the NISE Network succeeded in disseminating its educational materials to more than 200 institutions in the U.S. by 2009.[137] The distribution of the kits has allowed the NSF to claim that the NISE Network has a broad-reaching impact.

The museums and centers that host *NanoDays* have access to a diversity of resources (space, people, expertise, budgets) and are led by varied institutional priorities (some focus solely on children, some are oriented towards school groups,

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[137] Larry Bell, *3rd Annual Report (NISE Network): 10/2007-09/2008* Annual Report, Year 3 (Boston, MA: National Science Foundation, June 24, 2008); Larry Bell, "Where We've Been, Where We're Going" (presented at the ASTC, NISE Network Brunch, October 2009).

some are committed to activism). Thus, Paul Martin, another PI of the Network, said that the organizing members of the NISE Network decided that table-top exhibits presented during a predetermined week[138] were a way to provide a basic set of programs which could be shaped and interpreted in a variety of ways to meet the needs of all types of museums and science centers, even if they lacked prior experience with nanotechnology programming.[139]

The content and methods of *NanoDays*, however, demonstrated the ISE field's interpretation of the NSF's promotion of "impacts on society" of an emerging technology by relying on only a deficit model of science communication. I was told over and over that the educators began with the "basic principles" of nanoscience because that is what the *educators* needed to know. Multiple interviewees, be they the members of the Viz Lab or those like Rae Ostman who were crucial to the design and implementation of *NanoDays*, said that what all informal science education professionals shared was an ignorance of nanotechnology. Therefore, the content of *NanoDays* was designed, at least partially, to fulfill the ISE field's own knowledge deficits.[140]

Ostman, for example, in her work at Ithaca Sciencenter (where she was based), probably had the most experience with nanotechnology-related programming.

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138 Science centers and museums often highlight specific events during these "festivals." Not always, but often these festivals are sponsored by a third-party, like the NSF, in an attempt to raise awareness within a large number of institutions by coordinating a week long or weekend long programming events focused on a specific topic.

139 Paul Martin, "Interview by Author with Co-Principal Investigator of NISE Network," digital recording device, October 2009.

140 Ostman, "Educational Programming and Regional Meeting Coordinator."

The Sciencenter has produced the only two traveling exhibits on the topic, *Too Small to See* and *It's a Nanoworld.* The success and reception of these exhibits had made her acutely aware of the field's lack of experience with nanotechnology as a content area. When trying to explain not only why table-top exhibits had been a good choice for the Network but why the content of those exhibits was strictly limited to chemical and physical characteristics of the science, she indicated that the field needed to learn the specifics of the science before they could teach the more abstract characteristics or issues associated with the topic.

While informal science educators may have needed to understand more about the basic principles of the science which makes nanotechnologies interesting or powerful, the question remains as to whether these characteristics were and are necessary for ISE's publics. Scholars like Sheila Jasanoff have recently pointed out that the democratization of science may, in fact, require prioritizing citizens' perspectives and values (including what Leon Kass called the "yuck factor" or the "wisdom of repugnance") over those of professional science.[141]

Members of the NISE Network, including Ostman, lamented on multiple occasions that working on nanotechnology was challenging because publics were not even aware of its existence; thus, educators had to first create awareness of the subject before they could "foster understanding or engagement." This chapter documents the difficulties of working in a network where awareness among both publics and educators is assumed to be low. That assumption, and how the network decided to

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[141] Sheila Jasanoff, "Constitutional Moments in Governing Science and Technology," *Science and Engineering Ethics* 17, no. 4 (2011): 621–638.

approach science education in light of it, demonstrates the ISE field's lack of consensus in relation to emerging technologies. This chapter examines why, during the first five years of the NISE Network, the organizing educators[142] (whom I will henceforth call "the organizers") of the Network chose not to prioritize nanotechnology's "impact in society" as a way to hook visitors' interest.

Prioritizing and incorporating visitor values and perspectives on science and society could have been a way to draw awareness to the subject to produce more engaged, in-depth discussions of the principles of nanoscience and their importance. Leaders in the field, like Science Museum of Minnesota (SMM) president Eric Jolly and Association of Science-Technology Centers (ASTC) president Lesley Lewis, had declared as early as 2008 that in order to maintain its social relevance and authority the ISE community must make issues of science and society a priority, but the Network was slow to prioritize science and society issues into its programming.[143] To

[142] The primary work of the NISE Network was conducted by "working groups." In their final form, these groups were made up of one or two group leaders and anywhere from 5 to 10 other members. These individuals were scattered throughout the science centers and museums which made up the "core partners." They communicated most often via conference call. The group leaders communicated directly to the Executive Group, which was made up of the Principal Investigators. Some of these working groups included: Researcher Center-Informal Science Education (RISE), NanoForums, and Evaluation. I'm referring to any person who was a member of one of these organizing committees as "the organizers." This name refers to any person who contributed to the development of the educational products of the NISE Network. It does not include the evaluators and the evaluation team, however. Whereas individuals could be Vice Presidents of their museum, head of educational programming, or head of exhibits, and still be a member of the "Forums Group," for instance, evaluators were evaluators at their home-institutions and they served as evaluators for the NISE Network.

[143] Robert Garfinkle, "RACE: Fostering Community Conversations for Social Change," *ASTC Dimensions*, no. September/October (2008): 6–7; Lesley Lewis, "The

understand the tensions within the field of ISE that contributed to the NISE Network's prioritization of table-top exhibits which do not focus on issues of science and society, this chapter relies on a wide array of documents (online *NanoDays* kits, NSF annual reports, NSF proposals, blogs, secondary literature written by the organizers reflecting on *NanoDays*, and historical accounts of the development of science centers) in addition to in-depth oral interviews with organizers of the NISE Network and personal observations recorded during my own trips to *NanoDays* events.

This chapter demonstrates the role that *NanoDays* played in establishing standards and expectations of nanotechnology programming for informal science educators in the United States. It also demonstrates how the kits were the material representation of educator's knowledge. When *NanoDays* was distributed throughout the United States and promoted by the NSF as an example of its attempts to address emerging technology education in informal environments, it became the standard of how to address emerging technologies for informal science educators (especially those at science centers and museums with fewer resources) looking to learn how to present a subject unfamiliar to them. That standard illustrates the ISE field's and the NSF's adherence to and promotion of a type of informal education that fails to address the differences between teaching about emerging science and technology and teaching about more stabilized science and technology.

The following section describes the rise and importance of hands-on and table-top programming in U.S. science centers and museums. It examines why and how

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Road Ahead: ASTC's New Strategic Direction," *ASTC Dimensions*, no. September/October (2008): 3.

these programming styles become significant parts of informal science education, in order to understand how the table-top method of instruction and the historical priorities of science centers contributed to the NISE Network organizers' more focused interest in the physical and chemical characteristics of nanoscience. Within the larger context of hands-on and table-top programming, I will trace the history of *NanoDays* within the NISE Network and evaluate the significance of the creation of *NanoDays*, which moved the Network's focus away from large scale exhibitions.

History of Hands-on and Table-top Programming in the United States

The history of hands-on and table-top programming in U.S. science centers and museums shows why and how the politics and culture of ISE have determined what is valued as important about these methods and why they took hold in the field. The history of these developing ideologies, practices, and expectations played a significant role in shaping the NISE Network organizers' approach to emerging technology education.

There are only a few histories of the rise of hands-on, also known as interactive, museums or science centers and their methods.[144] Hilda Hein begins her account in 1957 with the Soviet Union's successful launch of Sputnik. In response to that achievement, Americans became increasingly worried about what seemed to be an inability to compete with the Soviets in science and math. As a result of this anxiety, the U.S. government renewed its interest in promoting science and math education

[144] Marvin Druger, *Science for the Fun of It. A Guide to Informal Science Education* (National Science Teachers Association, 1988).

inside and outside the classroom. The U.S. interest in science centers, which focused on hands-on learning, is thought of as a result of this focus on science and math.[145]

In *Science in Public,* Gregory and Miller have argued that during and following World War II, U.S. citizens were largely supportive of science and scientists.[146] Within only a few decades and with the rise of the Cold War, however, public concern over such things as nuclear proliferation and industrial pollution led to a highly ambivalent populace.[147] As a result, scholars and educators began a move to present science in a better light, hoping to dissuade people from fearing or rejecting science. These actions resulted in the public understanding of science (PUS) movement, of which the rise of science centers and their dedication to education was a part.[148]

Danilov's *Science and Technology Centers* starts its history of science centers with nineteenth-century technical museums and "The Exhibition of the Industry of All Nations," better known as the "Crystal Palace Exhibition" or the "Great Exhibition of 1851." These expositions equated a nation's value to the power and prestige of its technologies.[149] The Great Exhibition, in particular, sponsored by the Royal Society of Arts in London, was designed to promote British industry. What is now known as

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[145] Hein, *The Exploratorium*, 12.
[146] Jane Gregory and Steve Miller, *Science in public : communication, culture, and credibility* (New York: Plenum Trade, 1998), 3.
[147] Ibid.
[148] Ibid., 3 and 201.
[149] Ironically, according to Gregory and Miller, the Great Exhibition should have been a way to reveal the British Empire as far more advanced than the "foreigners" who were eventually invited to exhibit in South Kensington. Instead, the Empire was revealed to be both more advanced and "backward in science education and training." (198).

the Science Museum in London was a result of this exhibition.[150] Mostly famous for its wealth of scientific and technological artifacts, the Museum eventually added the "Children's Gallery" after World War II. The gallery was the Museum's first foray into hands-on or participatory exhibits.[151]

As part of this story, the Deutsches Museum (originally called the *Deutsches Museum von Meisterwerken der Naturwissenschaft und Technik* or The German Museum of Masterworks of Natural Science and Engineering) in Munich is said to be the first museum to present large technical objects to be manipulated by visitors. The museum, which grew most rapidly between 1903 and 1935 before being heavily damaged during World War II, contained many historical objects (an astrolabe, the first motor car, X-ray discharge tubes, and the first diesel engine). But it was Oskar von Miller's exhibit techniques, such as "full-size machine replicas, operating models, walk-through coal mine, a cutaway submarine, science demonstrations, and exhibits activated by visitors, that captured the imagination of the public and the attention of other museums."[152] Many museums, such as the National Technical Museum in Prague, the Technical Museum of Industry Crafts and Trades in Vienna, and the

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[150] Victor Danilov, *Science and Technology Centers* (Cambridge Mass.: MIT Press, 1982), 17–18.
The South Kensington Museum of Industrial Arts (later the Vitoria and Albert Museum) was founded in 1857 from the proceeds and materials of The Great Exhibition. Then in 1909 the science collections were separated from the decorative arts collections to form what is known today as the Science Museum. Gregory and Miller argue that the department of "Science and Art" which gathered the objects for the New South Kensington Museum was a result of the Empire's attempt to redress their revealed lack of science education and training (198).

[151] Ibid., 18.

[152] Ibid., 19–20.

Smithsonian Institute's National Museum and its Department of Arts and Industries in Washington, had benefited from international expositions and subsequently put the expositions' technological wonders on display, but the Deutsches Museum was the first to include components with which visitors could physically interact.[153]

The purpose of these large, technical museum exhibitions, according to F. Greenaway, was to "increase the means of industrial education and extend the influence of science and art upon productive industry."[154] Bernard S. Finn reports that these exhibitions were meant "to enlighten the people by exposing them to the fruits of technical progress."[155] In light of the World Wars and the Cold War, these objectives were reformulated in the writings of practitioners like Frank Oppenheimer, who had been inspired by the Children's Gallery and the Deutsches Museum, as he worked toward building a postwar commitment on the part of museums to the public appreciation of science and technology through visitors' physical interaction with scientific phenomena.

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[153] Ibid., 18 and 19.
Gregory and Miller (201) cite William Hackmann's "'Wonders in one closet shut': the educational potential of history of science museums" in *Museums and the Public Understanding of Science* edited by J. Durant (1992) to argue that interactive science has been going on since the 18th century when "hands on" demonstrations served as a key part of traveling lecturers demonstrations as well as university science courses. They go on to cite I.B. Cohen, "The education of the public in science in *Impact of Science on Society 3* (1952) pg 75, to argue that in late 19th century England this practice was stopped because it was believed that "…children should accept the word of scientific authority, rather than interact directly with nature itself." (201)

[154] Frank Greenaway, *A Short History of the Science Museum* (London: H.M.S.O., 1951), 5.

[155] Bernard S. Finn, "The Science Museum Today," *Technology and Culture* 6, no. 1 (January 1, 1965): 195, doi:10.2307/3100953.

In *Hands-on Exhibitions*, Timothy Caulton argues that a handful of other museums of science distinguished themselves, particularly in the 1930s, from "traditional" museums of science through their commitment to "interpretation and explanation alongside their exhibitions."[156] These included the Palais de la Découverte in Paris,[157] the Chicago Museum of Science and Industry, and the Franklin Institute in Philadelphia. In all of these museums, we can see the early growth of the hands-on museum philosophy, before the PUS movement or the rise of Cold War competitiveness.

The narrative which ties these preceding histories together, perhaps the most popular narrative in the ISE field today, begins with the opening of the Exploratorium in 1969.[158] Frank Oppenheimer, who had worked on the making of the atomic bomb with his brother Robert, became convinced that

> for many people science is incomprehensible and technology frightening. They perceive these as separate worlds that are harsh, fantastic, and hostile to humanity. There is thus a growing need for an environment in which people can become familiar with the details of science and technology and begin to gain some understanding by controlling and watching the behavior

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[156] Tim Caulton, *Hands-on Exhibitions : Managing Interactive Museums and Science Centres* (London ; New York: Routledge, 1998), 3.

[157] Jacqueline Eidelman, "The Cathedral of French Science," in *Sociology of the Sciences*, ed. Terry Shinn and Richard Whitley, vol. 9 (D. Reidel, 1985), 195–207.

[158] Incidentally, this legacy may be part of the reason why the NISE Network grant included the Exploratorium as one of the three "Core Partners." If a Network of science museums and centers is going be created in the United States, even those who know little about the field of ISE are going to ask questions if the Exploratorium is not part of such an initiative. Although not critical to this thesis, it is important to note that the history of ISE in the Untied States and Canada is more complex: The Ontario Science Center also opened in 1969, and both it and the Exploratorium built on lessons learned with the creation of the Pacific Science Center in Seattle in the early 1960s.

> of laboratory apparatus and machinery; such a place can arouse their latent curiosity and can provide at least partial answers. The laboratory atmosphere of such an "Exploratorium" could then be supplemented with historical displays showing the development of both science and technology and its roots in the past….The demonstrations and exhibits of the museum would have an aesthetic appeal as well as pedagogical purpose and they should be designed to make things clearer rather than to cultivate obscurantism or science fiction.[159]

Many of the stories of the Exploratorium's development argue that through the Exploratorium's "cookbooks" (how-to guides allowing other locations to reproduce modules or exhibits), the ways and means of hands-on exhibits were distributed throughout the world. Hein places particular emphasis on the implications of this dissemination. She argues that although the products spread throughout the world, it was Oppenheimer's philosophy of learning that had the greatest potential to affect change.

> No account of the Exploratorium could be complete without emphasizing the **educational** process, and I will stress the manner in which it is manifested in all of the museum's undertakings. Oppenheimer maintained that education was the museum's fundamental mission, although museums were not then recognized as serious teaching institutions for the general public. Thanks to the perseverance of the museum's supporters, museums are no longer confined to being repositories for scholarly research on the one hand and centers for tourist entertainment on the other. Their emphasis is much less on collecting rare and unusual objects than on fostering an appreciation for things that form our common world. The Exploratorium has shown a way to make perceptible what is normally unperceived and to make ordinary experience a topic of educational interest. It

[159] From "A Rationale for a Science Museum" by Frank Oppenheimer in Hein, *The Exploratorium*, 218.

> has also helped to shape the manner in which education is disseminated. It has the potential to do even more, for its interactive pedagogic technique contains a key to empowerment that could transform education on a broad scale and make it an avenue of general self-determination (emphasis added). [160]

Even today, science educators at museums and science centers debate how best to serve their visitors: through education that provides the "facts" or through education that seeks to empower? [161] There is little debate, however, as to whether, no matter what content educators believe should be conveyed, hands-on methods are the best methods to use in the institutions. The hands-on methods bear little resemblance to the "laboratory atmosphere of such an 'Exploratorium'" which Oppenhemier described. In fact, "supplement[ing] that atmosphere with historical displays showing the development of both science and technology and its roots in the past" is not a priority or expectation of hands-on practitioners. In addition, as we saw in the previous chapter, when the Exploratorium's educational methods do not fit what has

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[160] Ibid., Introduction, xvii.
Ibid., 66. Hein goes on to say that much of the philosophy of education which tied the exhibits together to achieve an overarching pedagogical goal was lost when the *Cookbooks* were disseminated, mostly because other museums were able to purchase "individual recipes and replicate the exhibits without absorbing the philosophy that underlies them."

[161] Devon Hamilton, "Are Science Centers Missing the Science" (presented at the Association of Science-Technology Centers Annual Meeting, Ft.Worth, TX, October 31, 2009); John G. Beetlestone et al., "The Science Center Movement: Contexts, Practice, Next Challenges," *Public Understanding of Science* 7, no. 1 (January 1, 1998): 5–22, doi:10.1177/096366259800700101; James M. Bradburne, "Dinosaurs and White Elephants: The Science Center in the Twenty-first Century," *Public Understanding of Science* 7, no. 3 (July 1, 1998): 237–253, doi:10.1088/0963-6625/7/3/003; Per-Edvin Persson, "Science Centers Are Thriving and Going Strong!," *Public Understanding of Science* 9, no. 4 (October 1, 2000): 449–460, doi:10.1088/0963-6625/9/4/307.

become ISE's definition of that "laboratory atmosphere," they are rarely pursued beyond the walls of the actual building in San Francisco.

Oppenheimer's declaration that there is a "need for an environment in which people can begin to gain some understanding [of science and technology] by controlling and watching the behavior of laboratory apparatus"[162] does not fully explain why the methods of hands-on science centers have become so popular, nor why the rise of these methods seems to have taken place across cultures and without particular attention to history or social context. One reason may be that the interactive or hands-on approach allowed informal institutions to officially shift their commitments to education as opposed to history or industrial preservation.[163] Traditionally, most science museums thought of themselves as collectors of culture; their allegiance was to preserving that culture as opposed to connecting to or, as Oppenheimer put it, "empowering" visitors.[164]

Another reason may be that the people who first started science centers believed that science was separate from culture and as such, when teaching people about science, content did not have to be situated in science's history. In fact, according to Oppenheimer, science ought not to be political (though it is unclear if that

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[162] Frank Oppenheimer and Exploratorium (Organization), *Exploratorium Records,*, 1957.

[163] Sheila Grinell, *A New Place for Learning Science : Starting & Running a Science Center* (Washington DC: Association of Science-Technology Centers, 1992).
It is worth noting that Frank Oppenheimer was for a time blacklisted because of his communist ties, and his brother Robert Oppenheimer had been pilloried and had his security clearance removed during the height of Cold War hysteria.

[164] Kelly Y. Fanizzo, "Collecting Culture and the British Museum," *SSRN eLibrary* (October 2006), http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1661937.

also means that science should not be historical).[165] The early supporters who contributed to today's science center culture argued that scientific phenomena are interesting, important, and meaningful regardless of their relationship to culture. Science "separate from culture" affords science center promoters and builders the opportunity to clearly demarcate the goals of the science centers from those of the preceding science museums. The contemporary field of ISE may be exhibiting yet another way in which its professional norms reflect the norms of science today. Sheila Jasanoff has described this as a world where we "let the scientist first decide, and name, the facts of the matter, and only then let everyone else's moral instincts come into play."[166] Like Jasanoff, I would argue "that [the] logic of 'facts first – values after' fails…in complex worlds such as those fashioned around the contemporary life sciences" or emerging technologies.[167]

Another reason for the success of this hands-on learning movement may be the new focus on museums for children. In contrast to Oppenheimer's vision, which largely focused on either expanding and complementing school education or providing adults with a space in which to learn and teach, many science centers, especially in the 1970s and 1980s, were founded solely for children.[168] These new museums were small-scale and often lacked any artifacts. Their primary purpose was to "provid[e]

[165] Macdonald, *The Politics of Display*, 16; Hein, *The Exploratorium*.
[166] Jasanoff, "Constitutional Moments in Governing Science and Technology."
[167] Ibid.
[168] Hein, *The Exploratorium*, 12; Caulton, *Hands-on Exhibitions*, 6.

exhibits and programs that stimulate curiosity and motivate learning."[169] In these popular spaces, the definition of science museums was reinvented, forcing the American Association of Museums and the Association of Science-Technology Centers (ASTC) to create alternative, broader definitions of education to make certain their educational philosophies covered what was being done in children's museums.[170]

The interest in children's museums is only one example of the trend toward meeting the attitudes and expectations of visitors that has taken over in the science museums community as a whole.[171] Museums are in fierce competition with other leisure industries, and in order to stay relevant, they have to serve the needs of their visitors.[172] In addition, their proliferation may have to do with the small to medium

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[169] The American Association of Museum's (AAM) definition quoted by Caulton, *Hands-on Exhibitions*, 6.

[170] This widening of the definition of the science museum had already occurred with the founding of ASTC. Today, most science centers without collections belong to both the AAM and ASTC, but originally, the AAM did not classify science centers as museums due to their lack of traditional collections.

[171] Danilov, *Science and Technology Centers*, 3.

[172] This argument has come up in numerous secondary sources and conversations with practitioners: museums must be attentive to their visitors needs in order to stay relevant. This continues to strike me as odd as it implies that prior to the last twenty years or so, museums totally ignored visitors' needs and interests. See, for example Steven William Allison, *Transplanting a Rain Forest: Natural History Research and Public Exhibition at the Smithsonian Institution, 1960-1975* (Ithaca, NY: Cornell University, 1995). Ignoring their interests and yet continuing to survive seems unlikely to me, even in a museum world where practitioners are dedicated to organizing and displaying their objects before finding ways to make those objects meaningful to the visitors. Nevertheless, I think this comment about visitor needs and relevance does represent recognition by practitioners that the visitor, the place of the museum in the visitor's life, and the place of the museum in its community has changed. Thus, most practitioners must be attuned to all of these changing needs if they are going to contribute to their institution's survival.

scale of most science centers (as opposed to their massive "museum of science" counterparts).

The Evolution of NanoDays

This history of *NanoDays* within the NISE Network and the significance of its creation for the field concentrates on how table-top exhibits became one of the NISE Network's primary focuses. *NanoDays* was a format that appealed to museums and science centers unaccustomed to working on nanotechnology. The content and format of *NanoDays*, which, according to the NISE Network and to NSF, were the reason for its uptake by the ISE community, also point out some important unsettled disputes within ISE about its own vision of learning and the place of the field in promoting a type of education in which publics and educators both contribute to defining nanotechnologies. The distribution of *NanoDays* throughout the ISE community led to an expectation within the science center community that the science of nanotechnology, and not its relationship to society or the values that construct that relationship, is the most interesting and important aspect to present.

NanoDays was one of the three primary educational programs that the NISE Network created and disseminated among its members for the first time in year three (2008) of the grant. When the NISE Network began in 2005, its organizing members assumed that it should focus the majority of its efforts on creating large exhibitions about nanotechnology that would be made through the collaborative efforts of the various NISE Network core partners.[173] By 2007, however, it became clear that large exhibitions were not the best format for the purposes of a network trying to share nanotechnological educational content. Large-scale exhibitions were expensive, difficult to update, and not portable enough to travel to different types of museums and easily fit into all of these museums' spaces.[174] Paul Martin said that large exhibitions did not allow for the kind of collaborative work the network was supposed to create. Furthermore, practitioners were unaccustomed to sharing their intellectual property when it was contained in an exhibition. Traditionally, museums or independent design teams created exhibitions and then other museums, those who could afford it and who could meet the requirements of the design team's layout, would rent the exhibitions.[175]

Most educators argue that a main aspect of a museum educator's job is to complement large-scale traveling exhibitions with appropriate programming that make the exhibits relevant to the visiting publics.[176] This programming includes table-top exhibits, theatre presentations, after-school classes, and a large array of other events that attempt to hold the visitors' attention.

Table-top exhibits like *NanoDays*, are smaller, more portable, and more easily modified than larger interactive or hands-on exhibit activities. They are always led by docents, onsite, real-life persons who interpret, demonstrate, and guide the programs.

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[173] Paul Martin, Vice President at Science Museum of Minnesota talking about their first meeting of exhibition designers, where all the invited museums brought exhibit prototypes to share and evaluate.
[174] Interview with Ostman, "Educational Programming and Regional Meeting Coordinator."
[175] Martin, "Interview by Author with Co-Principal Investigator of NISE Network."
[176] Hamilton, "Are Science Centers Missing the Science."

Typically, the exhibits can be put on and taken off a museum floor easily. They can be used as part of a larger presentation. They are not heavily resource-dependent. Docents are often barely-trained volunteers: high school students, retirees, or motivated graduate student scientists. Table-top exhibits often include objects from museum collections and/or hands-on tasks in which participants assist. By 2011 the *NanoDays* kits included eleven individual activities (only three of which were part of the 2008 manifestation), plus one poster component called "Nano and Society" (See Figures 2.1 and 2.2). This poster component marked the first time any focus or mention of issues of science in society had been included in *NanoDays*.

Since one of the goals of the NISE Network was to "create a sustainable service-oriented infrastructure that supports long-term efforts to educate the public about nanoscale science, engineering, and technology, as well as builds capacity in the field and within participating institutions,"[177] the network needed to distribute a product that would motivate individual institutions to begin to create their own nanotechnology educational modules. Large exhibitions, therefore, were not the ideal way for the NISE Network educators to embody nanotechnology concepts.

The programming working group, largely in charge of *NanoDays*, was able to create educational plans easily for these table-top exhibits and to recycle older plans or cookbooks to help fulfill the NSF goal of dissemination.[178] These miniature exhibits called for a docent or interpreter, which by 2007 the NISE Network educators had

[177] See, "Goals of the Network", Section II. Program Description, NSF 05-543 of *Nanoscale Science and Engineering Education (NSEE) Program Solicitation*.
[178] Interview with Greta Zenner, "NISE Net Regional Meeting Coordinator," June 2009.

come to believe was necessary to relay nanoconcepts.[179] They were also portable and inexpensive, another necessity for the affiliated NISE Network educators. Many of the smaller museums in the network did not have the time, money, expertise, or space to deal with or even to acquire larger exhibitions.[180]

NanoDays was not conceived until 2007. During that year the Network designed, tested, recruited sites for distribution, and distributed over a hundred kits. In about a year, the Network went from distributing little to no nanotechnology educational modules to other museums to supporting over a hundred museums in the simultaneous presentation of nanotechnology-oriented content, through the distribution of *NanoDays*.

At the regional Professional Development meetings, educators who admitted to knowing less than nothing about nanotechnology commented on how much they liked receiving a kit including everything that they would need to set up their table-top exhibits.[181] The compact and organized simplicity of a single box of materials appealed to them. Most of the educators who attended these regional meetings as part of the NISE Network's professional development felt as if they could manage smaller exhibits that were not resource-dependent and for which they held in their hands all of the set-up instructions including what materials to use, what to say to the visitors,

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179 Interview with author, Ostman, "Educational Programming and Regional Meeting Coordinator."
180 Participant Observation of the Northeast Regional Science Educators, "NISE Network Regional Meeting at the Ithaca Sciencenter," August 2009.
181 This sentiment was reiterated during the northeast regional Hub's break out sessions (run by Rae Ostman and Catherine McCarthy) of the 2009 NISE Network annual meeting.

answers to likely questions by the visitors, and website links to additional resources and information.[182,183]

If educators at these small museums had fed back to the NISE Network that *NanoDays* was not a useful or efficient tool, the organizers would probably not have continued to dedicate resources to it. However, at the 2009 annual meeting, for instance, it was recounted by organizers and educators alike that the *NanoDays* kits were a valuable means of introducing museums to nanotechnology content in the hopes that the museums would eventually dedicate resources to producing nanotechnology exhibits, apart from those offered for free by the NISE Network. And there was proof, at least anecdotally, that those institutions which presented nothing but what was in the box the first year they participated in *NanoDays* went on to independently add other events and programs in the years following.[184]

Larry Bell and a few other active members of the NISE Network recounted to me a story about the uptake by NSF of the "one-hundred-museum success story." They seemed to think it was interesting how a number that was not particularly important to the organizers was taken up by NSF leadership as an example of successful museum education. Apparently, Bell gave a talk where he spoke of

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[182] Ostman, "Educational Programming and Regional Meeting Coordinator"; Karen Pollard, "Exhibitions Designer and Regional Meeting Coordinator," June 2009; Zenner, "NISE Net Regional Meeting Coordinator"; Regional Science Educators, "NISE Network Regional Meeting at the Ithaca Sciencenter."

[183] Such a strong focus on table-top exhibits and other programming (like theatre), distinguishes NISE Net from other heavily funded museum enterprises. In addition, NISE creates, collects, and distributes "how to" manuals with each program that include materials needed, possible visitor questions, sources of additional information on the topic, in addition to evaluation results.

[184] Zenner, "NISE Net Regional Meeting Coordinator."

NanoDays and how NISE Network had distributed the kits to a hundred museums in 2008.[185] The next time Bell and other members of the NISE Network saw Mihail Roco, senior advisor for nanotechnology at the NSF, give a talk about successful nanotechnology educational initiatives, that talk included a slide where he informed the crowd that nanotechnology education had already spread to a hundred museums and would be in more the following year.

Every time this story was retold to me, the teller sort of cringed at the idea that *NanoDays* was being held up as the primary example of nanotechnology education in museums. Based on my interviews with Ostman, Zenner (the director of the University of Wisconsin's MRSEC education group and Chair of the Materials Research Society's Public Outreach Committee) [186] and others who were directly involved with creating *NanoDays*, this hesitance was mostly because the educators had not originally conceived of *NanoDays* as being of such primary importance to the NISE Network; the initiative was supposed to be merely one part of an overall agenda that would fulfill the NSF goals of distribution and professional development. *NanoDays* was supposed to be a makeshift way of successfully networking the museums, not a "best practices" example of how to present nanotechnology in an ISE setting. Even the programming committee was not completely enamored with using

[185] Bell, Ostman, and Zenner reported that in 2008 they originally only planned on distributing about 40 NanoDays Kits. However, since they had no trouble finding sites to which to distribute and they were still being asked by more institutions for kits, they decided to go ahead and declare 100 institutions as their goal.
[186] At the time, Zenner, now Zenner-Petersen, or just Petersen.

the metric of one hundred museums in relation to *NanoDays* as evidence of NISE Network's educational success, in part because of the simple composition of the kits.

The makeup of the kits reflects the assumed capabilities and preferences of the ISE community and the role of the NSF's evaluation requirements. For example, the "how to" instructions for the individual activities in the kits include discrete and measurable "main messages" or learning objectives[187] like "a nanometer is a billionth of a meter," "scientists use special tools and equipment to work on the nanoscale," and "the way a material behaves on the macroscale is affected by its structure on the nanoscale." If visitors could repeat these main messages, then evaluators and organizers could argue that *NanoDays* modules were an effective method of imparting information about nanotechnology.[188]

Two examples of table-top exhibits contained in the *NanoDays* kits are "Exploring Size, Scented Balloons"(Figure 3.2) and "Exploring Tools, Special Microscopes" (Figure 3.3). The NISE Network catalog describes "Exploring Tools" as "a hands-on activity in which visitors use a flexible magnet as a model for a

[187] The evaluators said that they took the definition and use of "main messages" which eventually got changed to "learning goals" from the work of Beverly Serrell, a scholar of visitor and museum studies whose main work focuses on improving museum labels.
[188] Christine Reich, "Public Impact Results for the Nanoscale Informal Science Education Network" (presented at the Association of Science-Technology Centers Annual Meeting, Ft.Worth, TX, November 1, 2009). Beverly Serrell, *Paying Attention: Visitors and Museum Exhibitions* (American Association of Museums, 1998).

scanning probe microscope. They learn that SPMs are an example of a special tool that scientists use to work on the nanoscale.[189]

Under "Try this!" educators are given step-by-step directions for what visitors are supposed to do with the magnet. This section is followed by "What's going on?" where educators are told how to explain the purpose of using the magnet to visitors. This is followed by a section describing the relationship of the experienced or observed phenomena to nanotechnology. These sections of the guide are supposed to demonstrate the "learning goal" or "Big Idea" that "Scientists use special tools and equipment to work on the nanoscale"[190] in addition to reflecting the Content Map (Figure 3.1), which defined NISE Net's definition of "NanoAwareness."[191]

[189] NISE Network, "Exploring Tools--Special Microscopes Guide," November 15, 2010, http://www.nisenet.org/sites/default/files/catalog/uploads/2515/toolsspm_guide_15nov10.pdf.
[190] Ibid.
[191] Marjorie Bequette et al., "Nanoscale Science Informal Learning Experiences: NISE Network Content Map" (Creative Commons Attribution, November 19, 2010), http://www.nisenet.org/sites/default/files/catalog/uploads/5250/nisenet_contentmap_19nov10_0.pdf.

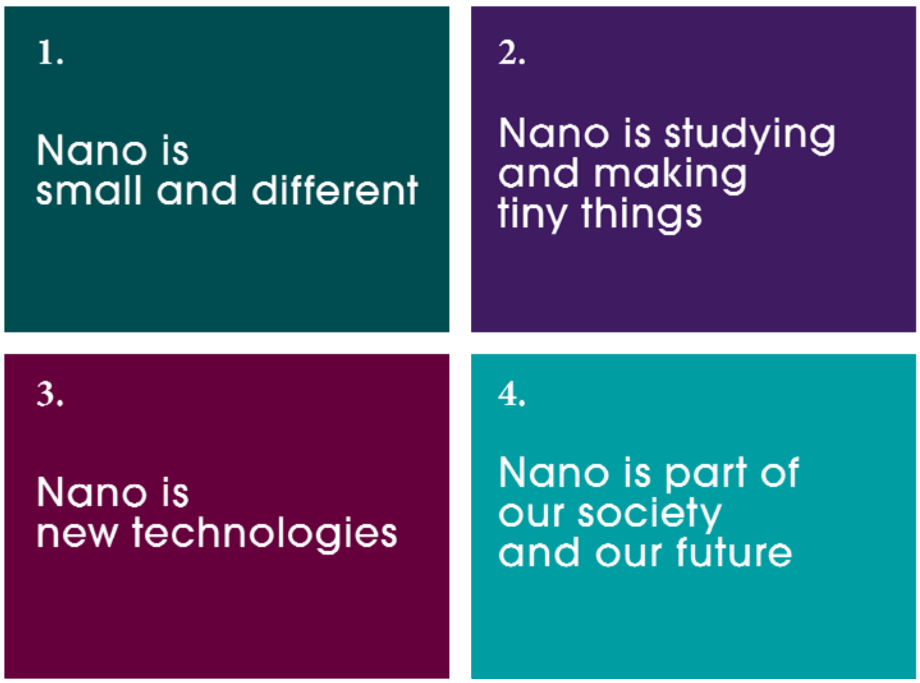

Figure 3.1 NISE Network Content Map

The NISE Network describes "Exploring Size" as an exhibit which "lets visitors use their sense of smell to explore the world on the nanoscale. They learn that we can smell some things that are too small to see, and that a nanometer is a billionth of a meter."[192] This exhibit is made up of six differently colored balloons which also

[192] NISE Network, "Exploring Size--Scented Balloons Guide," November 15, 2010, http://www.nisenet.org/sites/default/files/catalog/uploads/4130/sizeballoon_guide_15nov10.doc&ei=VtVOUMaeJ-

emit different smells when sniffed. The following excerpt is the first page of the guide which provides docents with guiding questions to ask visitors, an explanation of what the visitors are supposed to understand, and a "How is this nano?" section. By carrying out these objectives, visitors should achieve the learning goal of knowing that "a nanometer is a billionth of a meter" and fulfill the Content Map objective of realizing that "nanometer-sized things are very small, and often behave differently than larger things do." Figure 3.2, below, http://www.nisenet.org/http://www.nisenet.org/ is an excerpt of the "Exploring Size" guide given to educators.[193]

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nK2AX9_4GgCw&sa=X&oi=unauthorizedredirect&ct=targetlink&ust=13473455026 45712&usg=AFQjCNEkM5enWCnAZ-HtmQcDVAmPTw9FYQ.

[193] Ibid.

NanoDays
The Biggest Event for the Smallest Science!

Exploring Size—Scented Balloons

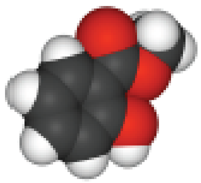
Try this!

1. Smell the balloons. Each one has a flavored extract inside it.
2. Can you identify all the different scents? Match the balloon colors with the scents listed on the poster.
3. Why do you think you can smell the extracts through the balloon?

What's going on?

Tiny scent molecules are leaking out of the balloons. They're too small to see, but you can smell them!

Your sense of smell works by identifying the shape of scent molecules. Molecules are made of particles called atoms that bond together. Everything in the world is made of atoms, including the balloon you're holding and the scented air inside it.



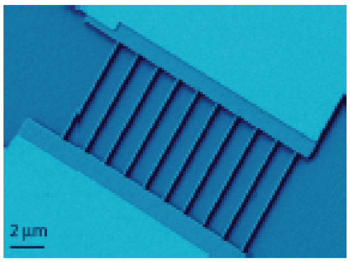
Molecular model of wintergreen oil

Scent molecules are so small that they can travel through the balloon membrane. In fact, they're so tiny that they're measured in nanometers! A nanometer is a billionth of a meter.

Air gradually leaks out of a tied balloon because the molecules inside the balloon move through the pores of the balloon's skin, in a process known as ***diffusion***. Air always diffuses from areas of higher pressure to areas of lower pressure. An inflated balloon has greater air pressure than the air around it, so the air inside the balloon gradually escapes.

How is this nano?

A nanometer is a billionth of a meter. That's very, very small—too small to see with just your eyes. We can use our sense of smell to explore the world on the nanoscale, because we can smell some things that are too small to see.



Biosensor with silicon nanowires

Nanoscale science focuses on the building blocks of our world, atoms and molecules. Scientists use special tools and equipment to detect and manipulate tiny, nanometer-sized particles.

In the field of nanotechnology, scientists and engineers make new materials and tiny devices. Researchers are creating tiny, nanometer-sized sensors that can detect very small concentrations of chemicals. Some of them work the way your nose does: by detecting the different shapes of molecules in the air.

Figure 3.2 Exploring Size—Scented Balloons

NanoDays
The Biggest Event for the Smallest Science!

Exploring Tools—Special Microscopes

Try this!

1. Take a magnet. You're going to pretend it's a ***scanning probe microscope***, a tool that "feels" a surface to find out what it's like.
2. Remove the "probe strip" from the side of the magnet.
3. Turn the magnet over so it's black side up. This is the surface you're going to feel.
4. Hold the probe strip the way it's shown in the picture, and pull it slowly across the magnet from left to right. What do you feel?
5. Now pull the strip across the magnet from top to bottom, again holding it the way it's shown in the picture. Does it feel different?

Left to right **Top to bottom**

What's going on?

The magnet is a model for how a special tool, called a scanning probe microscope (SPM), works. It lets you "feel" something that you can't see: in this case, a magnetic field. The north and south poles run in alternating bands across the magnet.

You feel the strip bump across the surface when it's pulled across the bands, because it's alternately attracted to and repelled by the poles it encounters. When the strip is pulled parallel to the bands, you don't feel the bumps because it's always attracted to the surface.

A scanning probe microscope similarly works by "feeling" something you can't see with your eyes. But in addition to detecting magnetic fields, an SPM can also detect lots of other kinds of things about a surface: nanometer-sized hills and valleys, atoms, conductivity, friction, stiffness, and more.

SPMs use a super-sharp tip to move across a nanoscale surface. By dragging this tip around on different surfaces and recording the bumps and grooves, scientists are able to piece together what a surface looks like at the atomic level.

These tools can even detect and make images of individual atoms, which are much too small to be seen with a regular microscope.

Tip of an SPM, magnified 1000x

How is this nano?

Scientists use special tools and equipment to work on the nanoscale. Scanning probe microscopes allow researchers to detect and make images of individual atoms and other things that are too small to see.

The invention of scanning probe microscopy was a great breakthrough in the field of nanotechnology. Once scientists could make pictures of individual atoms and the world of the nanometer, they could begin to manipulate and study things at this super-tiny scale. (A nanometer is a billionth of a meter.) Without the SPM, nanotechnology wouldn't be where it is today!

Figure 3.3 Exploring Tools—Special Microscopes

There is no mention of risks in these guides for docents. But in the "Exploring Scent" exhibit, there are multiple warnings for educators about the dangers of latex.

Idea number four of the Content Map – "Nanotechnologies have costs, risks, and benefits that affect our lives in ways we cannot always predict"[194] – is not explicitly fulfilled by any of the exhibits in *NanoDays*. Only the posters make reference to this aspect of the Content Map. These two exhibits are representative of all of the exhibits included in the kits. The materials are simple: magnets, nail polish, balloons, etc. Many of the learning goals could be entirely separated from nanotechnology and still be fulfilled and there is never any direct statement to guide educators about issues or questions associated with nano in society.

Only activities which included the main messages were considered able to be evaluated and therefore included in the NISE Network catalog (see Chapter 2, "Art, Artists, and the Wrong Kind of Science Education").[195] The type of evaluation applied to each activity was determined by the Network Executive Group (aka the Principal Investigators) and the evaluation group, neither of which was directly involved in the educational programming group's design of the *NanoDays* content. During a session presenting the results of the "Nanoawareness" evaluation,[196] it became evident that these groups (the programming group, the Network Executive Group, and the evaluators) held differing opinions as to what criteria could define *NanoDays* as having successfully contributed to "awareness, understanding, and/or

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[194] Bequette et al., "Nanoscale Science Informal Learning Experiences: NISE Network Content Map."
[195] "Public Impact Results for the Nanoscale Informal Science Education Network."
[196] "Public Impacts Summative Evaluation: Nanoawareness Year 4 Report | NISE Network," accessed September 11, 2012, http://www.nisenet.org/catalog/evaluation/year4nanoawareness.

engagement" and whose "awareness, understanding and/or engagement" was supposed to be bolstered by this program.

The NISE Network performed evaluations of *NanoDays*, building on evaluations carried out by an independent contractor, Inverness Research. These evaluations illustrate what the NISE Network believed visitors should be learning from their experiences at *NanoDays*. In particular, the evaluations point to the NISE Network's definition of awareness[197] and identify *NanoDays* as having "broad reach" but an "uncertain impact" in the field. I will place these evaluations into context using the perspectives of evaluators, NSF program directors, PIs, and educators, in an attempt to understand how the NISE Network is divided as to how to achieve a more certain impact with programming like *NanoDays*.

NISE Network evaluators learned that the majority of their visitors walked away from *NanoDays* programs with the ability to articulate the learning objectives, but without the ability to relate the learning objectives to the words "nanotechnology" or "nanoscience." In the following excerpt, one of the then-head evaluators Kirsten Ellenbogen explains these results during the ASTC 2009 annual meeting session on the Nanoawareness evaluation:

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[197] According to the summative evaluation conducted by Barbara Flagg of Multimedia Research "The evaluation focuses on awareness, defined here as the breadth and depth of familiarity with nanotechnology, as it is the first stage of learning about a new concept." pg vi of Barbara Flagg and Valeria Knight-Williams, *Summative Evaluation of Awareness of Nanotechnology by the Museum Public | NISE Network* (Bellport, NY: Multimedia Research, September 29, 2008), http://www.nisenet.org/catalog/evaluation/summative_evaluation_awareness_nanotechnology_museum_public. For NISE Net, Multimedia Research worked on front-end analysis in year one and summative evaluation in years two and three.

> Well, there's this whole question of vocabulary. So the main messages really came through loud and clearly. However, the term NANO, nanoscience, nanotechnology, whatever you want to call it…did not come through as clearly.
>
> For people who saw the "Wheel of Nano" program. It's kind of a program that sounds like [its name]… WHEEL OF NANO.
> 83% were able to articulate some or all of the program's main messages, but only 53% used any form of the word Nano in the interview [survey].
>
> If you take the surface area demonstration, right?
> 77% get the main message. 5 % of those people mention the word nano.
> In other examples, 0%. Nobody interviewed or doing the surveys mention nano, but they got the main message.
> Is that a problem?
> This is why, now this is year four, and the team is taking this and thinking ok…what's our goal? How are we going to deal with this?
> There was an exhibit in the very early stages of testing...it was about the concept of a nanoelevator that would go up to space, using nanotechnology.
> It had the word nano, in some form or another, probably every third word? Would that be accurate? And when people walked away from that they could talk about nano this nano that. Yeah this is about nano.
> It was not an enjoyable exhibit. It was not an interesting exhibit. It didn't meet any other criteria.
> The field knows how to make people say vocabulary if they want to, but then it doesn't get across the main messages necessarily.
> So this is exactly the question that they are considering right now.[198]

These main messages seem to be necessary because they are discrete and measurable.

To paraphrase Ellenbogen slightly, "the field knows how to make people say

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[198] Kirsten Ellenbogen during Reich, "Public Impact Results for the Nanoscale Informal Science Education Network."

vocabulary if [educators] want [visitors to repeat certain terms]." The field can design exhibits in which visitors will afterwards state the subject of the content using the word for the subject, like "nanotechnology." However, stating that an exhibit was about nanotechnology does not necessarily mean, according to Ellenbogen, that the exhibit "get[s] across the main messages."

During this session of ASTC, the evaluators who were presenting the results of the "Nanoawareness" evaluation began a discussion with attendees about whether using the vocabulary of nanotechnology took away the educator's ability to convey "understanding." For the evaluators and PIs present at the session, it seemed that when people could articulate the main messages of programs they had achieved "understanding," but only when they could articulate that knowledge as related to nanotechnology was "awareness" achieved.[199]

Vocabulary, or whether the word "nanotechnology" is invoked by visitors describing what they learned, does matter. Evaluators and educators wanted visitors to do more than repeat certain vocabulary as a sign that their learning objectives had been achieved. However, they also seemed to believe that avoiding certain vocabulary as content, such as "nanobots" or "self-replicating," seemed to be a good way of avoiding conversations about the ambiguities associated with nano as a technoscience currently emerging in society. When does vocabulary matter?

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[199] "Relevance" was achieved when visitors could relate nanotechnology or anything in the program to any part of their daily lives. This will be discussed more in the next chapter on forums.

The NISE Network has been unresolved in its answer to this question. While PIs, NSF representatives, evaluators, and program designers all seemed to have an answer to this question, the overall approach to building programs was based on a belief that vocabulary is not a crucial part of learning the main messages. In fact, evaluators came to wonder whether educators were actually afraid of using nano-specific vocabulary because they were uncomfortable with it and therefore assumed their visitors would be intimidated by it as well.[200]

Vocabulary and its role in these educational modules seem to get at the fears and insecurities of the educators learning to manage an emerging science (as opposed to a stabilized one). While the PIs and the NSF clearly had a mandate to include a focus on learning about possible social and ethical issues, it was not until 2011 that *NanoDays*, the most prolific programming effort of the NISE Network, made any direct attempt (through the "Nano and Society" posters) to address that focus. Even more importantly, the NISE Network evaluators, like the one quoted below, have found evidence that it is possible to address social and ethical issues and yet educators have chosen not to do so.

> Yet what we're finding out from some of the product evaluations is that people *can* learn about societal issues through NISE Network programs. The interesting thing, going back to what are people [educators] doing, is that not many people in the network right now are choosing to employ programs that talk about societal issues.
>
> They are more likely to talk about and to employ the programs that teach about some of these fundamental

[200] Reich, "Public Impact Results for the Nanoscale Informal Science Education Network."

> scientific concepts. So there is any opportunity here for the network to build upon this work to say we know we *can* teach about societal issues through some of our shorter- term programs as well as our longer-term forum programs, and do we want to push that forward? Do we want to push and make sure that people are more likely to talk about societal issues? Or is it that we still think that it's not that important of an issue and it's ok for it to be a smaller subset?[201]

This quote reflects the NISE Network's approach to issues of nanoscience and society as of 2009. The evaluator's questions point out that the field of ISE, given the choice of programming about social and ethical issues or programming related to "fundamental scientific concepts," preferred the "fundamentals." The *NanoDays* creators were aware of this preference and therefore did not emphasize a focus on science and society in *NanoDays*. This preference by the field reflects larger trends in ISE, which prioritizes "scientific facts" over "values," but it is unclear whether the creators of *NanoDays* followed this trend because they did not recognize some fundamental differences between teaching and learning about emerging technologies and teaching and learning about more stabilized technoscience.

By examining *NanoDays* from the perspectives of both informal science educators and visitors, we can understand how, by fulfilling objectives like distribution, evaluation, and flexibility, *NanoDays* came to value certain aspects of learning that do not account for nanotechnology as an emerging technology. What does it mean to look at *NanoDays* from the perspective of the educators at the museum? Examining how *NanoDays* fit the needs of the museums is one way to

[201] Ibid.

understand how a network of museums and science centers with a wide variety of styles, sizes, methods, and expertise transfers knowledge across a field. The materialization of the network's knowledge and practices through the distribution of the kits represents pathways through which knowledge is spread. The task of creating educational modules which educators could use, no matter which setting the modules were placed in, led the NISE Network educators to embody their knowledge in table-top exhibits focused on properties of the nanoscale.

After two years of *NanoDays* distribution and evaluation, the "impact" of the *NanoDays* events, according to NISE Network's evaluation, was highest at locations where *NanoDays* kits were nested into other *NanoDays* events. Unfortunately, many of the museums which serve the smallest communities and run on the fewest resources, those which were happiest to get exhibit materials that were basically free, were ill-equipped to do this necessary nesting which made *NanoDays* effective.[202] Therefore, educators with the fewest resources and background in nanotechnology content produced *NanoDays* events using only the kits. Using only the kits resulted in what the NISE Network evaluators have called "low impact." Many visitors to these exhibits had no idea that they had even been to an exhibit about nanotechnology, even when the evaluators told them what it was about.[203]

As I previously mentioned, the creation of *NanoDays* was meant to fulfill an NSF expectation to "get nanotechnology into a hundred museums." To accomplish this, via a network model in which educators from a variety of institutions

[202] Ibid.
[203] Ibid.

collaborated to build educational modules and in which a variety of institutions would receive the materials, *NanoDays* kits had to be portable and customizable. The kits' knowledge had to be capable of changing forms, depending on the context of the presentation. In other words, upon receipt of a kit, educators had to be able to easily put together and modify the *NanoDays* kits to fit them into their museum space, resources, practices, and visitor expectations.

When a large-scale exhibition is rented and travels to a variety of museums, the original owners/creators of that exhibition stipulate the space in which the exhibit should be presented and the organization of the individual exhibit activities. Each museum is at liberty to complement the exhibit with programming of its own, but the spatial layout and presentation of the overall exhibition itself is supposed to remain reasonably consistent to ensure that the knowledge it conveys is also consistent. Because the exhibition has already been tested amongst a variety of visitors and the spatial layout, language, and overall presentation of the material chosen fulfills most of the exhibition designer's goals and the visitors' abilities, museums are encouraged to complement an exhibit with their own programming to tailor them to the locale without changing the exhibit itself.

In 2009 I participated in a session at ASTC about whether the "science" had been lost from science museums.[204] At that time, the *Harry Potter* exhibition, which was organized and sponsored by Warner Brothers, had just opened at the Boston Museum of Science. This discussion was one of the most heated of the sessions I

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[204] Hamilton, "Are Science Centers Missing the Science."

observed. Two primary voices rose to the top. One loud voice believed it was completely disgraceful that something that had so little to do with science could be presented in a science museum (and a well respected one at that). The other set of voices advocated for the practicality of an exhibition like *Harry Potter*. These voices believed that although the relationship of props from the *Harry Potter* movies to science was tenuous, the exhibition attracted many visitors. And without visitors, the science museums cannot achieve any of their goals, no matter what they are. Therefore, it is a museum's responsibility to pair other exhibits that are full of science learning with an exhibition like *Harry Potter*, possibly even pointing out scientific aspects of the exhibition which its own designers failed to appreciate. Science museums, in this view, should take advantage of having visitors who may not otherwise come to their institution by essentially luring them in with popular culture like *Harry Potter* and then bombarding them with actual educational experiences once they arrive.

This idea that museums were only doing their job if, irrespective of the content or style of the exhibitions traveling to their institution, they found a way to nest those exhibitions within the educational experiences of the museums and the expectations of visitors, is one that was shared by the NISE Network educators. After the first year, the kits were most highly rated by educators from museums that had little or no experience with nanotechnology exhibits. The kits were an opportunity to easily and simply have a go at putting nano into an institution. However, the "Nanoawareness" evaluations also clarified that only in the museums where the kits had been hacked or nested into other programming related to nanotechnology did they have any sort of impact on visitors. The first year of evaluation by Barbara Flagg's Multimedia Research company examined the kits in four museums (all working partners in the NISE Network and members of Tier 1), all of which had at least some kind of previous experience with nanotechnological content.[205] That year, Multimedia Research found both broad reach and some impact. Nevertheless, when the NISE Network performed their own study in the following year and looked at museums in the next layer outward (museums of Tier 2 who were not necessarily partners), the evaluators found *NanoDays* to have no apparent impact.[206]

For instance, at the Boston Museum of Science, which is one of the largest science museums in the United States, a leading member of the NISE Network, and an experienced presenter of nanotechnology content, *NanoDays* events bear little resemblance to the table-top kits of the NISE Network. This is partially because Boston has a longer history than most museums of producing nanotechnology-related programs. Their *NanoDays* events in 2011 included a stage presentation, table-top exhibits led by local scientists from MIT, Northeastern, Harvard, University of Massachusetts-Lowell, and University of New Hampshire, special guest presentations, product exhibitors like Raytheon and Konarka, as well as a Science Café, a permanent exhibit, and a handful of other activities. The MOS's experience gave them the opportunities to connect permanent exhibits, seemingly unrelated to nanotechnology, to the activities in the kits. For instance, MOS has a butterfly house, and it used this

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[205] Christine Reich, "Public Impact Results for the Nanoscale Informal Science Education Network" (presented at the Association of Science-Technology Centers Annual Meeting, Ft.Worth, TX, November 1, 2009).
[206] Ibid.

space as a way to discuss some of the learning goals in the kits, relating them to the self-cleaning properties and colors of the butterflies' wings.[207] Unsurprisingly, the Boston Museum of Science is one location where NISE Network evaluators found a "high impact."

This use of the NISE Network's kits contrasts with the initial presentation undertaken by Edventure, which is a children's museum in Columbia, South Carolina. This museum represents the next layer outward in the NISE Network (Tier 2). Edventure is not a partner in the NISE Network, but it did receive a *NanoDays* kit. Even with Edventure's partnering with the nanotechnology researchers at the University of South Carolina (USC), it took a few years of participating in *NanoDays* before the museum learned how to nest the activities into other programs and activities. Professor Catherine Murphy, an organic chemist at USC, an active participant in the Citizens' School for Nanotechnology sponsored by USC's NanoCenter, told me she was less than overwhelmed by activities she witnessed at the museum's *NanoDays* event. Mostly, she was disappointed by what she thought was an uninteresting presentation of science content. She went to *NanoDays* at the children's museum even though she has no kids, because she not only researches nanotechnology but has dedicated herself to learning exciting and interesting ways to present the basics of the science to her students. Thus, she is always interested to see how nano is presented to the public at large.

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[207] Museum of Science, "NanoDays: The Biggest Event for the Smallest Science," *MOS, Events, Activities, NanoDays*, Spring 2012, http://www.mos.org/events_activities/events&d=2526.

She described the first year of *NanoDays* as a few young people, maybe college age, sitting around at tables with a few craft materials. It was not apparent to her how those materials related to nanotechnology, nor was it apparent to her that the people at the tables knew how the materials related to nanotechnology. There were no other programs or events corresponding to the activities at the tables and few visitors to the museum were paying any attention to them.[208] In subsequent years, Edventure has begun playing a more active role in the NISE Network by sending participants to NISE network sessions at ASTC, for instance. The CEO has also taken an interest in presenting nanotechnology to their publics. Here she discusses how *NanoDays* helps make connections between nanotechnology research and public's everyday lives.

> How much does the public really know about nanotechnology research and development efforts happening in their own backyard? This exhibit seeks to engage South Carolina residents with hands-on demonstrations showing this technology used in everyday life as well as highlighting current nanoscale science exploration efforts and their implications for the future.
>
> *NanoDays* provides a tremendous opportunity to learn more about the amazing world of nanotechnology and gain a deeper understanding of how some of the Earth's tiniest materials are making significant impacts on various industries, including alternative energy, environmental control and healthcare.[209]

By 2011, *NanoDays* at Edventure had become more interesting than a few slouchy teenagers, balloons, and construction paper. These first impressions seemed to be evidence of the tension between NSF's triumphant announcement that the Foundation

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[208] Catherine Murphy, Spring 2008.
[209] Catherine Wilson Horne, president and CEO of Edventure.

had spread nanotechnology education to a hundred institutions and educators' understanding that presenting the kits is not enough. Edventure now nests the hands-on activities into lectures and activities directed at adults. Although much less ambitious than the MOS in this respect, the museum has made small strides in supporting the *NanoDays* activities through professional development training, such as that offered by ASTC.

In 2011, *NanoDays* events included a slight change toward inclusion of social and ethical issues, looking at the risks and benefits of nanoscience through the inclusion of the posters. This change signifies the beginning of the NISE Network's attempts to address the power of the potentially negative implications of nanotechnologies despite its discomfort with managing reactions to those potentially negative effects while simultaneously trying to build a network.[210] On the morning of April 2, 2011, I went with my husband and our five-month-old daughter to the Ithaca Sciencenter's *NanoDays* events. I had been to *NanoDays* at the Sciencenter in previous years as well as observing the table-top kits at the annual meetings of the Materials Research Society and ASTC. I wanted to visit again this year, however, because it was the first year that the *NanoDays* kits addressed social and ethical issues

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[210] I am not equating "social and ethical issues" with approaches to "science and/in society." As will be made more evident in Chapter 4, addressing "social and ethical issues" focuses more on risks and benefits where as "science and/in society" addresses a range of values and perspectives which shape and are shaped by nanotechnologies. In addition, the NISE Network eventually came to describe the goal of its first five years as "network building" and the goal of its last five years as "infusing science and society throughout the network." I know, based on my interaction with NISE Network members during those first five years that this divide was not thought of explicitly while the work was being carried out. Instead, this description reflects a recognition of what happened, not what they had tried to accomplish.

of nanotechnologies directly. Moreover, *NanoDays* at annual meetings is not representative of *NanoDays* events in museums, since museums are now encouraged to incorporate the kits into programming and events that are unique to each location. Therefore, I was curious to see how the Sciencenter was incorporating *NanoDays* into the museum as a whole, especially since members of the Sciencenter were leaders in designing and implementing the *NanoDays* kits.[211]

The Sciencenter has two floors. On this day, the majority of the *NanoDays* stations were upstairs, with a few smaller exhibits and signs leading visitors toward the stairwell. Placing the table-top exhibits upstairs enabled the Sciencenter to incorporate *NanoDays* into their permanent nano exhibits. It also allowed visitors to easily access the "crafts room" where visitors could make model molecules.

At the Sciencenter, where a majority of the activities in the kits were developed, the individual exhibits were used in a way very different from the methods employed by the Boston Museum of Science. In Ithaca, the exhibits were the primary focus of *NanoDays* and were complemented by a stage presentation by a scientist, a movie (created by Portland's Oregon Museum of Science and Industry (OMSI)) that no one attended, and the building of a two-story carbon nanotube made of balloons.

Upstairs, the *NanoDays* kits were set up at tables, most of which were concentrated in an activities room in the back corner of the second floor. Most of the table-top exhibits were set up similarly. A rectangular table was positioned close to a

[211] The work of the exhibits and programs at the Sciencenter Ithaca focuses on hands-on exhibits for children, generally under the age of 13. In addition, the Sciencenter, particularly Rae Ostman, has played a significant role in creating nanotechnology related exhibitions for the field and in participating in the Network.

wall. Behind that table were one to four volunteers standing or sitting. On the table were some NISE Network documents and the objects which were the focus of that lesson. These objects included balloons, nasturtium leaves, pieces of stain-proof fabric, construction paper, and a variety of other odds and ends that serve as the tools with which to demonstrate each hands-on exhibit. While we were there, young children and their parents walked up to the tables and handled the materials or put together the crafts available. Meanwhile the volunteer docents, who ranged from high school students to graduate students and other adults, explained how the crafts or other props demonstrated a physical or chemical characteristic of nanotechnology.

In the activities room, posters from the social and ethical implications unit were hung on the walls behind the tables. Incidentally, these posters were designed by the members of the *NanoForums* team, not by the *NanoDays* team. They included questions like "What's hidden in *your* sunblock?" and "Does nanotechnology belong in toys?" (See Figures 3.4 and 3.5).

Figure 3.4 "What's hidden in *your* sunblock?"

Figure 3.5 Does Nanotechnology belong in toys?

There was no discussion directed by the docents about these questions, nor were people paying particular attention to them (though they were hard to miss with their black backgrounds and pointed comments and questions). Their lack of integration into the overall *NanoDays* activities implied that attention to risks and benefits or an interest in promoting discussions about social and ethical issues was not of high priority to the creators of this *NanoDays* event. From the visitors' perspective, these posters made little impression not because they were not impressive, but because none of the docents at *NanoDays* was making any attempt to include their messages in the learning objectives of the activities.

The *NanoDays* events' heavy reliance on the physical characteristics of materials led to the tendency of all the table-top exhibits to make nanotechnology seem fairly similar to older technologies. In fact, most of the methods of relaying nanotechnology concepts had to do with showing how what goes on at the nanoscale is really not that different from what happens at other scales. This perspective might originate in the perception of educators who recognize that "innovative" technologies promoted as the "next big thing" are rarely as new and different as the promoters would like us to believe. In fact, since educators found the qualities of nanotechnology difficult to manage, they did what they do best: they related those unique qualities to aspects of natural history and science with which they are already confidently familiar.

The marginalization of these posters which focused so directly on engaging with social and ethical issues of nanotechnology reveals the extent to which *NanoDays* could have been about most any science. The posters represented the first time that NISE Network visitors might have had the chance to realize that the risks and benefits of nanotechnologies could be dramatic, long-lasting, and unique to this particular science. On this day, *NanoDays* educators did not avoid using the word nanotechnology, but rather, even in the presence of these posters, they avoided any discussion connecting nanotechnology to possibly negative social outcomes.

Perhaps the primary reason that the NISE Network programming team decided to concentrate on nanoscience and the physical characteristics of nanoscience over issues of science in society is (what they perceived as) the field's abilities and the complexities of developing a network.[212] Given the history of science centers and their current reliance on specific philosophies of learning and communication combined with their lack of experience in professional collaborations, the NSF might have assumed that, given the choice between physical and chemical characteristics of a science and the role of that science in society, the science center philosophy will ensure a focus on scientific phenomena before a focus on science in society. Since the NSF required the formation of a certain type of network, in which a small group of practitioners would collaborate and build expertise in a particular area and a larger group of practitioners would benefit from the distribution of the fruits of that collaboration, *NanoDays* may very well have been the best means of quickly distributing the products of those collaborations. In addition, in the same way that the tensions between the methods of artists and those of scientists in Chapter 2 revealed the challenges of managing the vocabulary (see quote by P. Winfrey) associated with the presentation of an emerging technology, *NanoDays* reveals another strategy to account for the complexities of presenting an emerging technology. In this case, educators focused solely on physical and chemical phenomena and avoided any discussion of the unpredictable, ambiguous, or undecided.

Conclusions

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[212] Bell, "Where We've Been, Where We're Going."

The definition of education for the educators who created *NanoDays* seems to focus on factual content, particularly the chemical and physical characteristics of nanoscience. The ISE community argues less about approaches to education than about the content of those approaches. It is fairly well-accepted that there will be numerous approaches to ISE, but the content of those approaches is often contested. Those contestations make evident the scientific and pedagogical priorities held by the practitioners. The form and especially the content of *NanoDays* in the first five years of the NISE Network laid out a type of ISE about emerging technologies which excluded visitors' or educators' values from defining nanotechnologies.

NanoDays demonstrates a response to the pressure to network museums and spread nanotechnology content, programming, and professional education regardless of other factors. Given that *NanoDays* was put together reasonably quickly, it demonstrates a belief by educators that the most valuable science education must be quantifiable and that science is separate from culture. This long-standing belief, whether conscious or not, is obvious in the practices of the educators and leads to assumptions about the "right" education regarding nanotechnologies. These assumptions include, most importantly, prioritizing the straightforward teaching of basic scientific properties above the examination of science in society or culture. The NSF may have actually asked the ISE community to perform tasks that it was incapable of accomplishing; NSF may not have recognized ISE's commitment to communicating the "facts" of science before those of "science in culture." The NISE Network organizers did what they usually do, but their accustomed methods could only fulfill the NSF's expectations of dissemination to 100 museums without addressing societal impacts.

The move to define informal science learning as hands-on science learning has led science center educators to assume that the "best methods" of science education involve scientific content divorced from its context. In all the secondary literature I read about "effective"[213] exhibitions and in all the exhibitions I have visited or studied, educators and evaluators alike maintain that the exhibits that are longest-lasting, most effective at conveying messages, and best-liked by visitors are those which nest the details of the science into the context in which it matters. For instance, at the Smithsonian's Air and Space museum designers have coupled a purely hands-on exhibit demonstrating the scientific principles of flight (and directed at ages six and up) with a story of a couple of bicycle makers' move toward successful flight and stories about the mysteries and history of early long-distance flight. With each failed flight, visitors can see the difficulties inventors had in mastering Bernoulli's Principle.

The organizers of the NISE Network felt that such exhibitions were not possible because our knowledge of an emerging technology is constantly changing, and given the time scale of exhibitions, they could not adjust accurately to those changes. Does what we understand and believe about all science not change? Why would it not be interesting to tell a story about using nanotechnologies in the military, especially while the country's attention was turned toward two different wars?

[213] It's important to note here that the evaluations almost never try to study the "affects" of museum experiences. See Beetlestone et al., "The Science Center Movement," 7.

Demonstrating to visitors the physical characteristics of an emerging science is important. But a lasting effect on those visitors may only be achieved when we understand why those physical characteristics matter. What is more valuable, learning about Bernoulli's principle or articulating why those early attempts at flight failed (even if one cannot remember the name "Bernoulli")? NISE Network educators and NSF alike believed that more was at stake in educating the public about nanotechnologies than in other projects these practitioners have conducted. If that is the case, if there is a possibility of improving or damaging our world through earlier education about a new technology, why should we not connect the interesting principles of this tiny science to the social and cultural context of our daily lives?

CHAPTER 4

NANOFORUMS: THE ROLE OF ISE IN THE POLITICS OF SCIENCE

Introduction

The previous chapters have addressed how the primary activities of the NISE Network (namely *ArtNano* and *NanoDays*) did not account for the difference between teaching and learning about stabilized and emerging technologies in a museum setting. They also pointed out the difficulties the NISE Network had incorporating issues of science and society into the content of *NanoDays* and *ArtNano*. On the surface, *NanoForums*, the NISE Network's third main educational focus, faced neither of these challenges.

NanoForums was designed with two specific assumptions in mind: 1) that issues of science and society can be addressed among adults in a conversational format, and 2) that conversational formats are the best method to include the social and ethical issues pertaining to emerging technologies in general and nanotechnologies in particular. This chapter's primary purpose is to demonstrate the combination of factors that rendered irresolvable the question demonstrated by the development of *NanoForums*: can and should science museums intervene in the politics of science?

This chapter demonstrates this tension as a means of understanding what seems to be at stake for these educators, the future of the science museum. Brad Herring, one of the primary designers of *NanoForums*, and editor of the "*NanoForums* Manual," states:

> Science centers internationally are exploring new models for engaging adults and older youth in dialogue and deliberation on issues related to the societal, ethical and environmental implications of technology. This democratization of public policy deliberation is a strategy for stimulating learning by both scientists and the public and *for revitalizing the role of science museums in the life of the nation.* These efforts lay the groundwork for an exciting new role for science centers as a bridge between scientists and the public. (emphasis added)[214]

The *NanoForums* team believes that "democratiz[ing]…public policy deliberation is a strategy for stimulating learning."[215] *NanoForums* is an example of a new model of engagement. This chapter argues that the challenges *NanoForums* faced show science museums' (re)acknowledgement of their need to examine their purpose and their future existence. Museums dedicated to science and other topics have a history of periodically reevaluating their missions and practices in an attempt to keep their doors open.

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[214] Herring, "The NISE Network Public Forums Manual," 7.
[215] Herring, "The NISE Network Public Forums Manual."

The museum is a part of and reproduces culture.[216] Given their multidimensional positioning within society, the museum and the people who make it up are constantly working to balance and negotiate relationships among a board of trustees, leaders of the museum, educational programmers, community leaders, financial supporters, and users. Each exhibition, each project, has a unique story explaining how all of these partners (and more) played a role in producing the goals, methods, and content of the museum programs.[217]

NanoForums is no different. The tensions among the goals of the cooperative agreement with NSF, the ideals of museum presidents who are leaders in the ISE field, the ideology of educators, and the competing visions of the role of the museum in facilitating learning and defining engagement are obvious in this case, because even before there was a NISE Network, individuals who became key participants in the NISE Network and in developing *NanoForums* were committed to moving the museum's work toward a focus on citizen involvement in emerging issues of science

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[216] Ivan Karp, Steven Lavine, and Rockefeller Foundation, *Exhibiting cultures : the poetics and politics of museum display* (Washington: Smithsonian Institution Press, 1991); Ken Arnold, "Presenting Science as Product or as Process: Museums and the Making of Science," in *Exploring Science in Museums*, ed. Susan Pearce, New Research in Museum Studies (London; Atlantic Highlands NJ: Athlone, 1996), 57–78; Susan M. Pearce, *Exploring Science in Museums* (Continuum International Publishing Group, 1996); Bettina Messias Carbonell, *Museum Studies: An Anthology of Contexts* (John Wiley & Sons, 2012); MacDonald, *A Companion to Museum Studies*; Macdonald, "Chapter 1: Exhibitions of Power and Powers of Exhibition: An Introduction to the Politics of Display"; Gieryn, "Chapter 12: Balancing Acts: Science, Enola Gay and History Wars at the Smithsonian"; Susan Pearce, *Museums and the Appropriation of Culture* (London ; Atlantic Highlands NJ: Athlone Press, 1994).

[217] A good example of these tensions is demonstrated in Sharon Macdonald's ethnographic study in Macdonald, "Authorising Science.".

in society.[218] *NanoForums* was simply an opportunity for these key participants to begin to understand the tensions surrounding this (re)envisioning of the museum's societal role. Because professional development and distribution is a necessary component of all NISE Network programming, the creators of *NanoForums* quickly noticed practices and beliefs that could have been more easily overcome had they only encountered them in their home institutions.

This chapter demonstrates that what could have been viewed as an idiosyncratic characteristic of an individual institution came to be recognized as a tension within the science museum community more broadly. The distribution of *NanoForums* required the *NanoForums* team to take into account the tendency of many educators (and museums) to be uncomfortable with museums promoting themselves as places where citizens can interact with the politics of science. The educators (especially those who thought of themselves as scientists and/or defenders and preservers of "science") were often the individuals most uncomfortable with acknowledging the place of the museum in science politics. In other words, the *NanoForums* case demonstrates what scholars in STS have understood for a long time: those who believe in science actually hold a misconception about what science is.

To explore these tensions and demonstrate the role they played in creating *NanoForums*, and thus creating a definition of public engagement within science

[218] Troy Livingston, "Interview by Author with NCMLS Vice President of Innovation and Learning", December 16, 2009; Larry Bell, "Interview by Author with Co-Principal Investigator of NISE Network," digital recording device, November 30, 2009; Brad Herring, "Interview by Author with Forum Group Leader", October 31, 2009.

museums in the United States, I rely on oral interviews that I conducted with Troy Livingston and Brad Herring of the North Carolina Museum of Science and Industry, Principal Investigator Larry Bell of the Museum of Science Boston, and members of the evaluation team who preferred to remain unnamed. I also relied on informal interviews conducted with educators during round table discussions at the NISE Network and ASTC annual meetings. Lastly, I focused on the *NanoForums* manual and evaluation, created by the *NanoForums* team for distribution to museums planning to host forums.

As this dissertation's introduction explains, this chapter takes as its context a handful of studies presenting and examining educational models (like deliberative dialogue) to address, create, intervene in, or explain citizen engagement in science. In particular, I pointed out how Jasanoff's concept of "civic epistemology,"[219] Cozzens's and Woodhouse's concept of "proknowledge,"[220] Wynne's (and Levine's) analysis of "local knowledge,"[221] and finally Miller, Guston et al's[222] concept of "anticipatory governance" provided conceptual tools that the *NanoForums* team tried to use as they attempted one of the most complicated aspects of public education about

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[219] Jasanoff, *Designs on Nature*.
[220] Cozzens and Woodhouse, "The Politics of Knowledge."
[221] Wynne, "Misunderstood Misunderstanding."
[222] D. Barben et al., "Anticipatory Governance of Nanotechnology: Foresight, Engagement, and Integration," *The Handbook of Science and Technology Studies* (2007): 979; Clark Miller, "Informing Anticipatory Governance of New and Emerging Technologies," 2005, http://cns.asu.edu/cns-library/year/?action=getfile&file=35&section=lib; D. H. Guston and D. Sarewitz, "Real-time Technology Assessment," *Technology in Society* 24, no. 1 (2002): 93–109; Clark Miller et al., "Nanotechnology & Society: Ideas for Education and Public Engagement," *Center for Nanotechnology in Society* (September 7, 2007): 1–18.

nanotechnologies. Namely, the "users"[223] of nanotechnologies, a group that is not limited to visitors to museums but includes any members of society who interact with and shape nanotechnologies (and yet are frequently unaware of nano), have difficulty identifying themselves.

This lack of identification became evident to not only the *NanoForums* team but the NISE Network as a whole. In response, the Network decided to try to link nanotechnologies more directly to publics' everyday lives. A few changes in practices demonstrate this awareness.

1. The *NanoForums* team decided to change its name, and its focus, to Science and Society.
2. By the end of year four, the NISE Network had moved toward looking for ways to alter and amend current museum programming and exhibition to include nanotechnology content. The assumption was that these already created modules were evaluated as relevant to visitors; therefore, adding nano content would help visitors further understanding nano's relevance to them.
3. Partially based on feedback from the network, the NISE Network made subjects like "Energy and the Environment" and "Nanomedicine" priorities. To do this, nanotechnologies were introduced through the frames of medicine, energy, and the environment.

[223] Steven Epstein refers to this group as "patient groups."

Once the NISE Network began trying to incorporate nanotechnology programming into existing programming related to these other topics, the Network organizers questioned whether "nanotechnology" was really worth addressing as a separate, important topic.[224] When the assumption which underlies all of their work is that the public is unaware of nanotechnology but should be aware of it, can these educators ever move away from the limitations of some sort of deficit model of understanding?[225]

This chapter analyzes a few specific tensions and the stories around these tensions to try to understand the role that *NanoForums* played in demonstrating and then proposing solutions to these conflicts. In particular, I examine the relationship between the "technology attentive" or the NSF's concept of the "attentive" citizen[226] and *NanoForums* as a site where the social and ethical issues of nanotechnologies are addressed as recommended in the cooperative agreement. I examine the meaning of education, particularly adult education, within the story of the development of *NanoForums* and ISE as a whole. I analyze discussions and demonstrations of the ideologies of educators involved in the development of *NanoForums* and the forums' users to understand what they determine to be the "right" type of learning associated

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[224] ASTC 2009 Annual Meeting

[225] Bruce Lewenstein and Dominique Brossard, "A Critical Appraisal of Models of Public Understanding of Science: Using Practice to Inform Theory," in *Communicating Science: New Agendas in Communication* (New York: Routledge, 2009), 11– 39.

[226] The NSF's surveys or *Indicators* examining attentiveness were originally at least partially based on Miller's concept of the "technology attentive citizen." John Miller, "Scientific Literacy: a Conceptual and Empirical Review," *Daedalus* 2, no. 112 (1983): 29–48; Jon D Miller, *The American people and science policy : the role of public attitudes in the policy process* (New York: Pergamon Press, 1983).

with the social side of science in museums. And finally, I portray how the NISE Network defines “engagement” and what role that definition plays in shaping the future of science museum work by examining the competing visions of the role of the museum in “learning” and “engagement.”

For clarification, I repeat here the descriptions I provided in Chapter 1 of the actors who played the most important role in *NanoForums*.

Educators: In this chapter, I make a distinction between educators who were directly involved in the development of the programmatic activities of the NISE Network and educators who were *not* part of the development of educational modules in NISE Network but who instead represent the ISE community which uses NISE Network products. Those who use the products but are not “organizing members” of the NISE Network participate in the annual NISE Network meeting, in the regional development workshops, and at regional meetings associated with the NISE Network.

Programming educators: Also known as the “programming group” or “educational programming working group,” this is a group of educators within the NISE Network who were directly involved in the planning and implementation of table-top exhibits and programs, including *NanoDays*. This group was led by Rae Ostman from the Sciencenter in Ithaca and was made up of members from all of the Tier One Institutions. The group is larger than *NanoForums*, having approximately twenty members with ten or more participating actively at any one time.

***NanoForums* team**: This was the working group which designed and implemented *NanoForums*. It was made up of six members, one of whom was an evaluator. All members were actively involved.

ISE community or field: This refers to the Informal Science Education community, including all of NISE Network as well as those practitioners not directly related to the Network.

Museum and ISE leaders: This refers to the presidents of the ISE institutions including both museums and professional groups like ASTC.

NanoForums Development

NanoForums developed out of the Museum of Science Boston's interest in technology education. Larry Bell, a Vice President at Museum of Science Boston, a PI of the NISE Network agreement, and a leader in the ISE field, told me that when his museum became one of the first to focus on technology education, there was an immediate assumption that it would also focus on how to present issues of science and society within the context of technology education. NISE Network's *NanoForums* built on this experience. To the Network, however, *NanoForums* was a compartmentalized way to address the field's burgeoning interest in making issues of science and society a priority in museum programming. This move came within the context of Eric Jolly's and Lesley Lewis's advocacy for the future of ISE as policy- and society-oriented. Nevertheless, the NISE Network was not initially prepared to instill these priorities into everything it did. It took a less uniform approach and saw science politics as having only a confined, specific place within its overall work goals. There was always tension around the prospect of infusing issues of science and society into all of the educational modules. In fact, as demonstrated by the discussions surrounding the "Nanoawareness" evaluations mentioned in Chapter 3, there was an assumption that visitors do not find interesting social and ethical topics when included in programming and exhibits.[227]

In the NSF's original "Call for Proposals," the NSF suggested that the network which would develop from the call should take into account that nanotechnology "has

[227] Livingston, "Interview by Author with NCMLS Vice President of Innovation and Learning."

technological, economic, environmental, social, and ethical dimensions that may change the world in which we live. Increased understanding and appreciation of the potential for nanoscale science and engineering will be needed to create an informed citizenry and a competitive workforce. It is therefore imperative that our schools and informal science education organizations offer developmentally appropriate and scientifically accurate learning opportunities."[228] NSF suggested that grant recipients should approach issues of science and society in the form of a forum or science café. This inclusion of social dimensions in the CFP was part of a 2002 Congressional mandate requiring that part of the funds spent on nanotechnology address social and ethical issues.[229]

The present chapter demonstrates how the NISE Network interpreted this suggestion as a mandate and never moved away from this form. Larry Bell created the momentum behind *NanoForums* through his role as a PI from a museum which had already prioritized the presentation of science in its social context. The following analysis of interviews with Livingston, Bell, and Herring will demonstrate how those members of the NISE Network who created *NanoForums* justified its existence by invoking speeches, institutional prerogatives demonstrated in museum mission statements, leadership statements by people like Jolly and Lewis about representing politics in science in museums, and original recommendations by the NSF. Although the *NanoForums* team did consider other format options (Citizens' School of

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[228] *Nanoscale Science and Engineering Education (NSEE) Program Solicitation*, Introduction.
[229] Joanna Mariel Radin, "Scientists in government : framing the environmental and societal implications of nanotechnology," 2004.

Nanotechnology, Danish consensus conferences, and other more general types), none of those options were chosen. Instead, the information that the *NanoForums* team learned about how these other formats worked was used to design the forums model.

The *NanoForums* group became a haven within the NISE Network for people who were interested in promoting the science museum as a space for redefining museums themselves. The team, made up of educators from five institutions, volunteered to take part in developing the forums as a way to participate in a type of work to which they did not otherwise have access. All of the team members felt strongly about the important role issues of science and society should play in museum spaces, and they believed that working on the *NanoForums* team might be a way to have influence over the direction museums take in addressing the place of politics in ISE.

During my time observing and interviewing members of the NISE Network, I easily noticed a difference between the majority of informal science educators' approaches to program and exhibit development and the approaches and ideologies of the *NanoForums* team. Most educators with whom I spoke, especially those who were not directly involved in producing work for the NISE Network but were interested in benefiting from the work the Network created and distributed, felt strongly that for visitors the museum was a trustworthy source of information and it was their duty to maintain that trust by only presenting what they interpreted as "the facts." In their minds, these were the unequivocal characteristics of science. For example, during an informal conversation at the 2009 annual NISE Network meeting, as evidence of their adherence to the "facts," educators from a science center in New York state recounted to me an anecdote in which a home school organization asked to be led on a tour of their science museum. The group requested, however, that the docents make no mention of dinosaurs and, most importantly, that they leave out any discussion or exhibits which made up any of the narrative related to evolution. The science educators refused. They felt very strongly that these aspects of the exhibits that the home school group wanted them to avoid engaging with were in fact part of "the facts" portrayed in the museum. The home school group was welcome to interpret these "facts" however they would like, but the educators were not comfortable omitting them from the narrative contained within the museum.

This story pointed out that for these educators narratives such as the theory of evolution were undoubtedly part of the "facts." This was not the only story I was told in which the set of "facts" to which the educators referred seemed to be a discrete body of knowledge that those who believed in "science" understood to be "the truth."[230] In many ways, the educators were more adamant about defending "science" than many of the scientists with whom I have spoken. They seemed to believe that part of their job was to present these facts in the "correct" narrative, one without politics or opinion to cloud the message. This perspective stood in contrast to many of the *NanoForums* team members, who described to me their goal of teaching people about "science as a way of knowing, a way of learning, a way of thinking."[231]

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[230] During my time participating in round table discussions, I observed a number of conversations about "maintaining the neutral place of the museum."
[231] Livingston, "Interview by Author with NCMLS Vice President of Innovation and Learning."

The power dynamics between different groups within the science museum or center and the role of those dynamics in shaping the work and atmosphere of the institutions are nothing new. Those dynamics differ according on the focus of the museum, be it a more traditional museum of science, a natural history museum, a science center, or a hybrid. Because the NISE Network was a self-selecting network (members chose to participate or were invited by those who wanted their expertise), it was quickly obvious to me how these institutional dynamics were playing out in the field as a whole. For instance, in the NISE Network, individuals who considered themselves "educators"[232] (often because they represented some version of an "educational programming group" within their home institution), took charge of *NanoDays*. *NanoDays* (until 2011) contained no content relating nano to society or science to politics. *NanoDays*' content was wholly made up of the physical and chemical characteristics of materials, molecules, and atoms. Individuals with an interest in the future role of the museum, teaching science as a way of knowing, portraying the relationship between science and society, or methods of educating

[232] It is important to remember that these "educators" differ from more general "educators" who were not "organizing members of the NISE Network. The previously mentioned group who discussed the homes school anecdote included only people who did NOT design any part of the NISE Network's educational activities. The reference to educators in this sentence is referring, but not limited to the members of the "Educational Programming Group," people who designed educational activities for the NISE Network and who were in some way associated with their own institution's "Educational" programming. In other words, they were not associated with exhibit design, curation, evaluation, or any of the other labels found to distinguish the different working groups of ISE institutions.

adults chose to take part in the creation of *NanoForums* and not in *NanoDays* or in the programming group.[233]

As mentioned in Chapter 3, these individuals who considered themselves "programming educators" were highly dedicated to producing interesting, up-to-date, inspiring, and fun educational modules that helped visitors understand some of the primary characteristics that make nanotechnology unique, fascinating, and challenging to understand. Many of these educators also wore multiple hats as they moved back and forth among their roles as performers, evaluators, docents, and leaders of professional development who could in turn help others become performers, presenters, evaluators, and program designers.

This programming group was dedicated to maintaining its institutions as vibrant and important places of learning and discovery for their communities. Many of these educators were actively involved in making their institutions more accessible to more people through their development of public school programs in which every third-grade child would get the opportunity to come to the museum, in creating wheelchair-accessible exhibits or adjustments for vision-impaired visitors, in recognizing and adjusting programming to fit the changing needs of the local community through Spanish-language programs, and so on. Rae Ostman, for example, was the leader of the programming group, the lead developer of *NanoDays*,

[233] Some of them were eventually assigned to the group, like Brad Herring, but his role was minimal. During the calls I sat in on, he only spoke to introduce himself or answer a direct question related to scheduling of NanoForums events

and the NISE Network's organizer of the Diversity, Equity, and Access (DEA) working group.

Even though these organizers of the NISE Network do not see themselves as "re-envisioning" the future of the museum, they are dedicated to improving, updating, and growing that which they believe the museum has proven to do best. Although these individuals were leaders of the field, the significant differences between their priorities and the priorities of the leaders who designed *NanoForums* are worth accounting for when trying to understand the unresolved questions associated with ISE's approaches to presenting emerging technologies.

The primary difference that I saw between these individuals and those who organized *NanoForums* was that the programming educators were more willing to take into account the perspectives and requests of the greater ISE community. For instance, at the 2009 annual NISE meeting, the programming group led a conference-wide activity in which they accumulated and recorded the suggestions, especially related to programming content, of the educators who had used NISE Network activities but did not develop them. In contrast, the *NanoForums* team recognized that the greater ISE community might not be asking for educational experiences like *NanoForums*. Nonetheless, the team felt that *NanoForums* was too important not to introduce to other informal science educators and that those who were less taken with the idea of adult education, science and society, or dialogue modules could be convinced to host them. The programming educators, on the other hand, almost never tried to insert or distribute something to the greater community without first making sure that the module was something that they knew the community wanted.

In some ways, this makes sense: why force programming upon educators who do not want it or see a need for it? In other ways, the programming group's deference to the ideologies and priorities of less-involved, less leadership-oriented educators meant that the programmers' work (*NanoDays*, for instance) would never change the structure, priorities, or practices of the museum. Instead, *NanoDays* was just a way to get another content area into the overall curricula of the museums. In addition, their attitude and relationship to this greater community also meant that in some ways their work was at odds with the ISE leaders who were pushing the institutions to have more of a voice in science policy, community activism, and other issues of science in society.

Some origins of NanoForums

As alluded to above, the NISE Network's forums model was the brainchild of Larry Bell and the Museum of Science (MOS). With the publication of *Science for All Americans* and *Project 2061*(major science education policy recommendations from the late 1980s and early 1990s), the MOS became actively involved in making their "science and activity plan in sync with the move towards inquiry."[234] In an interview, Bell said that the MOS served as the "poster boys" for *Project 2061*, giving presentations at a variety of conferences where they explained how science museums could "use *2061* and *Science for All Americans* (and subsequent materials) when [they're] thinking about ISE."[235] From this experience (and the MOS director's interest in engineering education), Bell recounted that it was an easy step from

[234] Bell, "Interview by Author with Co-Principal Investigator of NISE Network."
[235] Ibid.

thinking about what he called “informal technology education” to creating forums.[236] “To us it[forums] was an important part of the whole technology learning package,”[237] he said.

Bell said that the MOS’s vision of forums was not “the typical presentation for adults where two invited speakers demonstrate their opposing views.”[238] Their forums were a round-table discussion amongst all of the participants focused on a question. The staff at MOS had witnessed a series of talks by researchers from North Carolina State University discussing Danish consensus conferences. They decided that they could do something similar to the citizen consensus conferences, “a learning experience for all of the participants.”[239]

With Bell’s and the MOS’s positions of leadership in the NISE Network, it seemed almost automatic that the NISE Network would pursue some sort of deliberative dialogue model as part of its repertoire of programming events. Members of the forum team investigated other models of deliberative dialogue including “National Issues Forums” or NIFs[240], “The decide game”[241], the Citizens’ School of

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[236] Ibid.
[237] Ibid.
[238] Ibid.
[239] Ibid.
[240] “National Issues Forums (NIF) is a nonpartisan, nationwide network of locally sponsored public forums for the consideration of public policy issues. It is rooted in the simple notion that people need to come together to reason and talk — to deliberate about common problems. Indeed, democracy requires an ongoing deliberative public dialogue. “ http://www.nifi.org/forums/about.aspx
[241] The Decide game was created by “FUND a two-year project supported by the European Commission to stimulate the use of discussion games and other debate formats in European cities for the development of a scientific culture at the local level.” http://www.playdecide.eu/about

Nanotechnology at the University of South Carolina,[242] and Danish Consensus Conferences[243] before settling on the two-hour model of the *NanoForums*. Troy Livingston, the Vice President for Innovation and Learning of the North Carolina Museum of Life and Science and a senior member of the leadership team of the NISE Network, said in an interview:

> We knew we would want to do it a little bit different from [the Danish style consensus conferences]. But we were pretty sure that we wanted to marry something between the informality of a science café and the formality of a citizen school of nanotechnology. Somewhere in the middle…. I think, yes, we knew it was going to look something like it wound up looking.[244]

The *NanoForums* team performed the bulk of their work in 2006 designing "Nanotechnology: Risks, Benefits, and Who decides?" Members of the team came from the Exploratorium, North Carolina Museum of Life and Science (NCMLS), Museum of Science Boston (MOS), Science Museum of Minnesota (SMM), and the Oregon Museum of Science and Industry (OMSI) (see Table 4.1).

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242 http://www.nano.sc.edu/outreachandeducation/citizensschool.aspx

243 "The consensus conference is a method which involves citizens and gives them the central role in assessing a technological problem or problem area. Participants are lay people without any specific relationship to the subject of the conference. In other words, they do not have any special prior knowledge or qualifications as regards the subject area. Citizens contribute by making their views known in the form of visions, concerns, values, holistic appraisal and everyday experiences. The consensus conference method is based on the premise that technological assessment cannot be limited to the legislative domain."
http://www.tekno.dk/subpage.php3?article=468&toppic=kategori12&language=uk

244 Livingston, "Interview by Author with NCMLS Vice President of Innovation and Learning."

Table 4.1 Museum Collaborators in NISE Net's Forums Team

Museum	Staff
Exploratorium	Veronica Garcia-Luis
Museum of Science	Larry Bell
Museum of Life and Science	Brad Herring
Science Museum of Minnesota	Dave Chittenden
Oregon Museum of Science and Industry	Amanda Thomas
Evaluation Coordinator	
Museum of Science	Christine Reich

All five institutions presented this forum at least once between May 2006 and September 2006.[245] The "Overarching Goal" of the forum was:

> To provide experiences where adults and teenagers from a broad range of backgrounds can engage in discussion, dialogue, and deliberation by:
>
> - Enhancing the participants' understanding of nanoscale science, technology and engineering and its potential impact on the participants' lives, society, and the environment.
> - Strengthening the public's and scientists' acceptance of, and familiarity with, diverse points of view related to nanoscale science, technology, and engineering.

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[245] Elizabeth Kunz Kollman, Christine Reich, and Anna Lindgren-Streicher, "NISE Network Forum: 'Risks, Benefits, and Who Decides?' Formative Evaluation" (Research and Evaluation Department, Museum of Science, Science Park, Boston, MA, 2009), 5.

- Engaging participants in discussions and dialogues where they consider the positive and negative impacts of existing or potential nanotechnologies.
- Increasing the participants' confidence in participating in public discourse about nanotechnologies and/or the value they find in engaging in such activities.
- Attracting and engaging adult audiences in in-depth learning experiences.
- Increasing informal science educators' knowledge, skill, and interest in developing and conducting programs that engage the public in discussion, dialogue, and deliberation about societal and environmental issues raised by nanotechnology and other new and emerging technologies.[246]

Larry Bell said that *NanoForums* was an opportunity to take something that his institution had been dabbling in and coordinate five other major institutions into the process of

> really working together. They met on the phone every week, developed everything and most of those institutions had never done a program like this before so the day they did their first program we were all on edge about how did it go? And I remember when David Chittenden reported back on their first program at the Science Museum of Minnesota he came on the phone and said "Oh Larry it was a disaster."
> And I went, "Oh no what happened?" And he goes "Ahahahaha IT WAS GREAT! People loved it! And they thought it was JUST the right thing for the museum to be doing! And so on and blah blah blah.[247]

Bell described creating the forums as "getting over sort of a hump where we were kind of used to the programming where we knew all the answers…. This was a case where we didn't know the answers."[248] He went on to describe other grants that members of

[246] Ibid.
[247] Bell, "Interview by Author with Co-Principal Investigator of NISE Network."
[248] Ibid.

the NISE Network were now a part of that included deliberation and dialogue programming. For Bell, at least, it was clear that NISE Network forums had "given [them] the opportunity to introduce the kind of program mode that [would] have an impact in ISE beyond nano."[249]

Developing Forums and Science and Society

As I mentioned previously, the six members of the *NanoForums* team were people who had taken a personal interest in the role of deliberative dialogue and/or adult involvement in ISE. The team was much smaller than the Programming team. Given this fact, there was less chance for turnover (only one primary member was laid off and thus had to be replaced during the most concentrated portion of forum development) and there was more room for individual voices to play a role in shaping the outcome of the forum program.

It was evident early on in my discussions with team members that the role of forums was unique in the NISE Network. Most obviously, *NanoForums* had been designed to attend to the NSF's interest in "impact on society." During my interviews, everyone always assumed that it was obvious why issues related to what the ISE field called "science and society" would be the *NanoForums* team's purview. As Troy Livingston stated:

> Nano and society should be [part of all ISE work], but we…no one has ever really been very successful at doing exhibits for example that ask SEI [societal and ethical issues] questions. SMM's recent *RACE* exhibit has been a pretty good, I think an excellent shot at that. Doing it around hard sciences is really challenging, so

[249] Ibid.

> while we would like to have had more of that science and society approach in theory, the actual doing of it is a big challenge (laughs).[250]

I replied:

> A lot of people have frequently brought up the same idea, that it's been really hard to include anything about science in society or SEI issues into exhibits and programming…

Livingston interrupted me to say:

> I'm going to put a caveat on that. It's not hard to include them. It's hard to make them effective. You can ask questions within the context of an exhibit. You can insert things; they don't work. They are ineffective exhibits…and people aren't interested in them. They're not interesting. These are the hard questions and you need a really attentive interested audience, I think, to really get into them.[251]

I found the notion that SEI issues or nano and society questions "are not interesting" as the rationale for why they were not pursued more uniformly by the field surprising because time after time, interviewees mentioned SMM's exhibition *RACE* as the best recent example of informal science education tackling a subject that was *entirely* focused on the relationship of science to society. Incidentally *RACE* was co-created by SMM (under the direction of Eric Jolly's and Robert Garfinkle's program on Science and Social Change referenced in Chapter 1) and the American Anthropological Association. No one mentioned the anthropologists' role in exhibit design, even though quite a few people (Bell and Livingston among others) mentioned

[250] Livingston, "Interview by Author with NCMLS Vice President of Innovation and Learning."
[251] Ibid.

the possible benefits of the future role of social scientists in the NISE Network. The *RACE* exhibition's entire goal was to portray how race is socially constructed.

The *NanoForums* team often brought up that although the ISE community at large was not pursuing issues of science and society as a top priority, the executive leaders of the field were. Brad Herring, from NCMLS, said:

> And I think there are some other institutions that are thinking about this and starting to do this, but I think we're really in the early stages of programming around the societal issues of science and society. I mean we heard this morning at the ASTC plenary speaker, from the new president [Lesley Lewis] that science in society is the direction of where ASTC is going. I think that we're at the beginning of it. [252]

The speech Herring referred to was that of Lesley Lewis. She was then the president of ASTC, the Chair of the Fifth Science Center World Congress, and the CEO of the Ontario Science Center. In the September/October 2008 issue of *Dimensions*, ASTC's newsletter, Lewis summarized the issues' theme in her article, "The Road Ahead: ASTC's New Strategic Direction."[253] Lewis wrote that "the main new ASTC strategy will be to address critical science and society issues proactively, in order to expand our reach, relevance, impact, and sustainability."[254] She said that ASTC's new focus had already been a priority of many of its members.

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[252] Herring, "Interview by Author with Forum Group Leader."
[253] Lewis, "The Road Ahead: ASTC's New Strategic Direction."
[254] Ibid.

It may have already been a priority of some of ASTC's members, but not many. By 2008, both the NCMLS and SMM,[255] key members of the *NanoForums* team, had presidents who had changed the mission of their museum to be one focused on social justice and life-long learning, and the members of the *NanoForums* team were all aware of these changes. As Troy Livingston put it:

> Eric Jolly is the president of SMM, and I don't know if you've seen their mission but he's changed it to be one of social justice's approach to science and society and I give him a lot of credit because that's a hugely…that's a ballsy mission to take on when we have not demonstrated as a field that we can be real successful at it. We have to get better. We have to do much better than we do.[256]

Jolly was an invited plenary speaker at the 2009 NISE Network's annual meeting. However, he was not comfortably received by the educators present at the meeting. During my informal conversations with some of those educators, they said that they felt that he was overly ambitious, optimistic, or unrealistic. They felt that his vision of the ISE world did not correspond to theirs. His program of "Science and Social

[255] SMM's mission: "Turn on the science: realizing the potential of policy makers, educators, and individuals to achieve full civic and economic participation in the world."

NCMLS's mission: "Our mission is to create a place of lifelong learning where people, from young child to senior citizen, embrace science as a way of knowing about themselves, their community, and their world."

[256] Livingston, "Interview by Author with NCMLS Vice President of Innovation and Learning."

Change" was all well and good, they said, but they felt that it was not representative of the ethos of most of their institutions.[257]

Troy Livingston characterized this discomfort best:

> "Here's what it boils down to. Should science museums take advocacy positions? Should we say: climate change is real? It is not a figment of somebody's imagination or a political agenda. The best science we have today says it's a fact. And as a result, here's what we think people ought to do about it. So where we would typically stop is here is what the science says today and here are some options that some people are offering us, the sort of equivocal approach that we would take. Is that the right role of the science center? Should we take it one step farther and say as a result the science tells us that we need to take action and the action, and the simple actions we can take is to use CFC light bulbs, for instance? That's the debate in the science center community. How far do we go?[258]

Livingston told me an anecdote which he felt illustrated some of the problems with exhibition designers having a political agenda. He said:

> There is this story about an exhibit developer at the Exploratorium. She created an exhibit that looked at water, bottled, distilled and tap. It allowed you to take a drink of each one of those kinds of water and then vote

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[257] As quoted in Chapter 1 of this dissertation: Robert Garfinkle, "RACE: Fostering Community Conversations for Social Change," *Dimensions*, no. Sept/Oct (2008): 7 "Under the direction of our president, Eric Jolly, SMM has launched the Science and Social Change Program to continue this work. We use the term "social change," which the International Council of Museums defines as "exploring issues with communities to contribute to their development," to advocate for strong collaboration between institution and community. We believe such collaboration is essential if a museum is to sustain a truly significant role in its community. We are now exploring new projects that emphasize the intersection of science and societal concerns and engage the public in dialogue."

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[258] Livingston, "Interview by Author with NCMLS Vice President of Innovation and Learning."

> on which one you thought was best by taking your crushed up cup and throwing it into a cylinder and you would walk behind and see the social aspect where all of the cups for people who voted for the same one you did were there. The exhibit developer's perspective on this and her desire and hypothesis was to demonstrate that tap water was just as good as distilled and bottled water. But what happened was people preferred bottled water and that made her crazy. Because that was not was supposed to happen.[259]

For me, this illustrated the question that these educators, whether forum developers or not, were all tiptoeing around: can they accept the possibility of visitors coming away from an exhibition or program having learned something with which the exhibition designers do not agree?

In fact, exhibits or programs which included SEIs or societal questions were not excluded because they are not "interesting" to visitors as Livingston described, but rather because the educators designing programs like *NanoDays* or *ArtNano* were unsure about including them because many answers to questions might not be predictable or controllable.

Larry Bell referred to this explicitly:

> We were getting over sort of a hump where we were kind of used to the programming where we knew all the answers…this was a case where we didn't know the answers.[260]

When an exhibition's content sticks to the uncontroversial aspects of science, it is much easier to define, predict, and control learning outcomes. When a crucial piece of the learning in a program involves the relationship of science and society to one

[259] Ibid.
[260] Bell, "Interview by Author with Co-Principal Investigator of NISE Network."

another, those learning outcomes become messier and less tangible (see Chapters 2 and 3).

One way the *NanoForums* team approached this tension was to articulate, specifically, that ISE could provide these sorts of open-ended interactions for adults. Herring asserted that

> adult programming is kind of new for museums. We're in the process right now of putting together a grant to try to work on adult education for museums because they just don't do it. Enough of it. I mean it's hard to really get into the societal implication for emerging technologies with young kids. So it really needs to work around adults.[261]
> You can get to these questions which we should try, but for the younger younger younger audiences we've got to teach them some of the basics first. So it's not something that they have done before and as they start to get into these educational programs for adults we want these museums to start thinking, hey we need to start educating the public on the societal issues around these emergent technologies because it is going to impact their lives and they need to start asking these questions so the next time they pick up the newspapers they kind of understand…. and they don't just read an article and believe it… they start to ask critical questions about what does this mean for me, what does this mean for my environment. So that's what we want museums to start doing and I don't really think they do it enough and they haven't done it enough. [262]

Bell also said that the community at large has not made adults a priority. He recalled receiving comments back from a grant proposal where a reviewer asked in the margin, "What's with all this adult stuff?" As Bell told me:

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[261] Herring, "Interview by Author with Forum Group Leader."
[262] Ibid.

> And the way I see it, public engagement activities like these forum activities that we do, is kind of like the interactive way of engaging adults in the topic. Not that you can't engage adults in the physics but you can sort of think of exhibits as very unique toys, kind of designed, kind of set up so that the kids get to play with them but set up to help them discover something or demonstrate some principle or whatever, but it's appealing to kids because they kind of get to play with them. And adults can be happy because kids are kind of learning something that might be useful to them at some point in their schooling or maybe in their career. But most adults probably don't see the laws of physics as something they are going to use in their everyday life.[263]

Livingston pointed out that not only did everyone on the *NanoForums* team have an interest in prioritizing science and society in museum work, they also "had a desire to connect with adults around current science and technology to start with. That it needed to be *nano*, I think was fine."[264]

The major themes of these comments, making museums dedicated to teaching visitors to think and ask questions, interactive education that adults care about, getting museums to teach critical thinking skills, and adult education focused on current science and technology or emerging technologies were priorities of the *NanoForums* team that made it stand apart from the other organizing members of the NISE Network. No one who was not directly involved with this adult education ever discussed or even alluded to the themes of teaching critical thinking skills or changing

[263] Bell, "Interview by Author with Co-Principal Investigator of NISE Network."
[264] This was not the only time that someone mentioned that "nano" as the object of study was not particularly important. NSF as well as the educators were not particularly interested in nano so much as they were interested in collaborating around an emerging technology. See Interview with David Ucko.

museums to provide learning experiences focused on issues related to emerging science, technology, and society.

Adult education became a way of balancing the *NanoForums* team's interests and the larger community's expectations. It seemed that providing programming on science and society related to adults and distributing that programming to the network was less controversial because few people in the ISE world were focused on adults. The *NanoForums* team wasn't stepping on anyone's toes because the work they were trying to insert into other institutions wasn't work that was already going on (or work that people were particularly interested in).

Brad Herring said, and I saw this toward the end of my time with the NISE Network and since I stopped conducting interviews with them, that the *NanoForums* team did develop an agenda in which they were changing their name to "Science and Society" in order to make themselves responsible for attending to issues of science and society for all educational modules in the NISE Network. Rather than compartmentalizing science and society approaches into forums, Herring reported that the *NanoForums* team wanted to think about the forum as just one program, with the team's real focus being progress towards the insertion of Science and Society into programs like *NanoDays*, for instance. As part of this, in 2011, *NanoDays* kits included provocative images and questions to try to incite some sort of discussion about nanotechnology's role in society (see Chapter 3).

In addition, Bell and Livingston said that the *NanoForums* team had tried to develop a closer relationship with the researchers at Arizona State University's Center for Nanotechnology in Society (CNS) as a way to learn how to integrate questions about the relationships between science and society into their work.[265] Most importantly, Bell reported that he felt that CNS's social scientists could help train NISE educators to deal with the open-ended learning experiences and questions that visitors and educators would encounter. Bell believed that part of the ISE community's discomfort with directly integrating and organizing programs and exhibits around science and society was due to its lack of confidence and training in this area.[266] Many or most of these educators have science backgrounds and view this expertise as situated in laboratory science, not in history of science, sociology of science, or even science communication. The kind of training CNS could provide might help the NISE Network become a leader in distributing not just programmatic modules but professional development skills to the networked institutions, according to Bell.[267] These skills might make the institutions more comfortable with the idea of introducing these Science and Society topics to children without feeling as if they are indoctrinating them.

Even for Bell, this was a concern that was on his mind:

> That's the part that I haven't dealt with…in my own mind yet, is when the program goes to something that

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[265] Bell, "Interview by Author with Co-Principal Investigator of NISE Network"; Livingston, "Interview by Author with NCMLS Vice President of Innovation and Learning."

[266] Bell, "Interview by Author with Co-Principal Investigator of NISE Network."

[267] Starting in the Fall of 2012, the NISE Network, in coordination with research from Arizona State University's Center for Nanotechnology in Society carried out four different professional development events to train NISE Network organizers to train their institutional staff to talk about and with issues of nanotechnology and society. I was able to attend one of these four sessions as a postdoctoral scholar for the Center for Nanotechnology in Society at Arizona State University.

> might seem like a political agenda, the malleability of the kids. Does it become indoctrination?
> How do you do it in a way that is not, does not lead in that direction?
> I think, I mean we've said in the forums area, that we're talking about adults and sort of older youth. And we've done a couple of things specifically with older youth groups in our experimenting over the last few years. But um, yeah, how to bring all of that to a broader audience. Younger kids?[268]

Definitions of Public Engagement and Public Understanding

Leaders from the *NanoForums* team, unlike the organizers of the programming group, were actively thinking about the theoretical and practical definitions of concepts like the public understanding of science and public engagement. Whereas the members of the *NanoDays* or Programming teams were aware of the ISE community's or the NSF's concerns with "raising nanoawareness," those teams were not as explicit about the roles their work played in defining a new model of engagement or learning. According to Troy Livingston:

> The other thing is we're talking models of engagement. This whole model of public engagement has really emerged during the period of this first 5 years. It's not something we talked about in the science center world before this project, this notion of mutual experiences. The qualities of emerging technologies as opposed to "dead science." Not focusing on things that are natural but the manmade world. So…I guess the point is that we sort of set out with each one of these things we thought about, we looked at a hill and we planned strategy to take that hill. So I'm not sure that…the answer to your question is all that sophisticated. We knew we wanted to try something that looked like forums. So we did

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[268] Bell, "Interview by Author with Co-Principal Investigator of NISE Network."

> forums and we knew we wanted to reach a lot of people so the strategy to do this was a festival. [269]

Perhaps this model or form was chosen for *NanoDays* because "festivals" are not something new for museums. Having a festival is a known way to get new content into a lot of ISE institutions in a reasonably short amount of production time (resources for festivals are less intensive than the resources needed for developing a traveling exhibition).

Educators also know that the content available at festivals is quick and dirty, so to speak. The visitors to the festival include a large number of people who are only participating because there is a festival; they are not frequent visitors or members of the institutions. Part of the point of the festival is to bring awareness to an area that was not previously part of an institution's programming and, through entertainment, to try to spark enough interest that new visitors will return. In spite of these fairly well-laid-out criteria, topics related to science and society were not included in the content of all NISE Network programming. The organizers of *NanoForums* believed that including science and society solely in *NanoForums* was justified, in part, by ISE's own definitions of public engagement, public understanding, and awareness.

The NSF dictated that the NISE Network attend to "awareness, understanding, and engagement." This phrase was repeated in NISE Network literature and presentations. During these presentations, however, the practitioners rarely said explicitly what they meant. The organizing members of the *NanoForums* team,

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[269] Livingston, "Interview by Author with NCMLS Vice President of Innovation and Learning."

however, repeated to me on various occasions their belief that the "science museum community does not think deeply about" different models of public engagement. For instance, Larry Bell said:

> On the other hand, there's a notion of public engagement with science as a different way of thinking about the connections between the public and science. And the public understanding of science model. And I think probably for the most part in the science museum community people don't think deeply about those ideas a lot? Or haven't?
> I think those from the public communication, the science communication realm, the university realm, do more. But we started to hear the term "public engagement with science" as the kinds of things we were doing within our forum programs as a part of this sort of technology curriculum that we had for informal science education here. And so we came to recognize the sort of philosophy or theory behind public engagement was kind of the notion of accepting the knowledge that the public brings to the table in a discussion around science and technology and its implications to society in a way that didn't seem to be present in the public understanding model.[270]

The individuals who designed *NanoForums* seemed to be more aware of the discrepancies and changes in the definitions of these terms by the field, in theory and in practice, than other members of the NISE Network. With very little prompting, they articulated what they saw as the field's interest in new forms of engagement, the vagaries of public understanding, and the limitations of building "Nanoawareness" (see Chapter 3). It seemed clear to them that whatever the definition of understanding, there was a relationship among awareness, engagement, and the type of educational module that provided this awareness and engagement. For the *NanoForums* team at

[270] Bell, "Interview by Author with Co-Principal Investigator of NISE Network."

least, it seemed obvious when these concepts were connected or demonstrated during certain NISE Network activities.

Engagement is a concept that has been used in a variety of different ways by practitioners and scholars. Unfortunately, there have been few attempts to track the variety of definitions in literature and practice.[271] From the perspective of these practitioners, the term "engagement" was developing a meaning for the institutions that it did not previously hold. This section further examines the relationship of this growing definition, made explicit by ISE institutions, to practitioners' priorities and commitments to developing a new role for science museums in public learning.

It has been unclear whether the NSF, when it laid out its three objectives of "awareness, understanding, and engagement," had in mind some of science communication's established notions of public understanding or public engagement. However, it did seem evident that the members of the NISE Network's *NanoForums* team were at some point made aware of science communication analysts' research and did begin to think "deeply" about how the definitions of public understanding and public engagement mapped onto the work the forums performed.

Again, Larry Bell:

> So I think that if you use engagement in the ways that science museums always have used engagement, well that's why we've got strange silly sand and that's why we've got stained glass demos and that's why we've got all that kind of stuff because it captures people's attention and they get sort of engaged in it. But if you

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[271] "Public Engagement - Informal Science Education Evidence Wiki," accessed September 9, 2012, http://iseevidencewiki.org/index.php/Public_Engagement. Accessed on August 1, 2012.

> are using engagement in this other way, then…through this project we've been able to get a bunch of museums into thinking about this kind of program and doing this kind of programming, and many are now starting to explore it in other ways. And I was sort of surprised by the extent to which it came out in the ASTC conference this year. There was that whole opening session which extended into breakouts afterwards in which everybody was encouraging museums to do this kind of thing and there was *no* talk of that three or four years ago. I mean other than sessions that we were doing, I don't know where it will go.

Bell is referring to the ASTC annual conference where Lesley Lewis urged the community "to address critical science and society issues."

I found this comment by Bell particularly valuable, because when I spoke with educators who were not part of the *NanoForums* team, they often had a hard time articulating a definition of engagement. More than one person told me that "everything we do is engagement." This is not altogether untrue, as Bell pointed out. Livingston told me that "70% of our revenue is from people coming through the front door. So we need people to visit. And we don't care what color [or] shape, we just need the numbers. Please come." If people are paying to come, that is already a form of engagement with science that those who don't show up aren't exhibiting. Nevertheless, institutional leaders like Eric Jolly and Lesley Lewis have an agenda that defines engagement as focusing on the role of the institution in the community and paying attention to learning about science and society.

For the NISE Network as a whole, it was less evident whether there was a shared definition or plan of action around the sort of engaged practice that Lewis and Jolly were promoting. The members of the *NanoForums* team were dedicated to this practice, even while the other organizers were less so. Given that some of the leaders of the *NanoForums* team were also leaders of NISE Network, and given that the NISE Network was required to distribute the forums program throughout the ISE community, the work of the *NanoForums* team is changing the practices and expanding the perspectives of other educators in the field.

Again, Bell:

> So I think the way it happened was that way back at the beginning we had sort of set the goal that there'd be some kind of awareness of nano, there'd be some kind of better understanding of the scale and the properties at the scale of nano. And that there'd be some kind of better awareness and understanding for dealing with the societal implications. And so we said I think from the very beginning those kind of three…basic awareness of nano, using nano as the opportunity to try to see if we could do a better job of dealing with atoms and molecules and forces at that scale. And trying to see if we could use nano to see whether science museums could address societal implications. In a more dynamic way than just the second paragraph on the label somewhere.

When looking at practitioners' definitions of understanding and engagement there is an obvious lack of the word "learning" in the discussion. Once practitioners moved away from physical-science-content-driven educational modules like *NanoDays*, where every table-top exhibit plan contains a list of learning goals achieved, practitioners seemed less able to articulate what counts as learning and how to assess it.

Some of the *NanoForums* organizers, however, had a clearer vision of what engaged learning should look like. Troy Livingston said:

> And my perspective is what our agenda is always about, I hope, getting people to understand better science as a way of knowing. To embrace it. To ask more questions. To hopefully leave with more questions than they came in with. And to have some sense of where to get the answers or different choices they might make. But really asking questions and thinking about how the world works. More so than I want them to understand the specifics of nano.

But this vision of learning was not one that was assessed in the *NanoForums* evaluation; the lack of assessment underlies tensions often found in the development of programming materials whose content is not typical. Programming learning goals and evaluation learning goals often do not line up. Whether this was because the evaluators had a different vision of what was important in the forums from that of the forum designers or whether this was because the forum designers did not see it as a top priority to be able to articulate the type of learning, I could not discern. It was evident, though, that at least in the case of the "Who Decides" Forum, the evaluation did not try to investigate types of learning, but assumed the same content-driven, facts-oriented approach favored by the evaluators of *NanoDays*.

This quote from the "Who Decides" evaluation illustrates my point:

> The two learning goals that the NISE Network Forums Team had for the "Who Decides?" forum were the following: 1) participants would have an increased understanding of nanotechnology and 2) participants would gain an understanding some of the potential societal impacts of nanotechnology. Participant reports of their learning indicated that these two topics were the most likely to be learned by the participants during the forums.[272]

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[272] Kollman, Reich, and Lindgren-Streicher, "NISE Network Forum: 'Risks, Benefits, and Who Decides?' Formative Evaluation," 21.

The learning goals and the participant reports of their learning matched up. However, "increased understanding" and "gain an understanding" are not very specific terms. It was unclear what role dialogue and deliberation were believed to play in the kind of learning participants took part in. People like Brad Herring and Larry Bell seemed to think that the kind of engaged learning that takes place in forums necessarily includes science and society content, deliberation and dialogue.

Brad Herring:

> I wrote something down that I thought was interesting at a session I just went to on where so what we want… we're definitely interested in public engagement. The public understanding is that top-down approach where it is you think of it as your expert up here and they are talking at the public. And there's no two-way communication back. So that the public are just sitting there understanding and they are not really getting engaged. The dialogue helps the public make long-term decisions, break deadlocks, go beyond polarized views, build confidence to make braver decisions, and increase legitimacy.
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> So in other words, a science café, for instance can have, the public understanding model for science café would be a scientist talks for 15 to 20 minutes, and you have a 20 or 30 minute Q and A and everybody goes home. There's a lot of people who never asked a question. A good majority of people who just sat there and absorbed. And then they walked away.
>
> So if there is dialogue or deliberation with the public and the scientists and they are all so if you break up into groups and you've got people sitting around the table. You've got different points of view being heard by this person. So this person over here, X person has four or five other people maybe more sitting next to them and so they get to hear other points of view that aren't theirs so it makes them a little more exposed to the certain topic. And then it also, from the standpoint of the scientist who gets to hear the public and their opinions, they can then help guide their research and understand.

There was no consensus as to how the dialogue and deliberation model would intervene in policy, although the members of the *NanoForums* team from North Carolina were excited about the possibility of scientists and publics engaging together in a conversation to validate and learn about one another's perspectives. The role of scientists as participants and not only as experts seemed an avenue through which the practitioners (at NCMLS, at least) thought the participants in these deliberative modules could communicate in a back-and- forth fashion. This model seems to include the acknowledgement that Bell mentioned of lay expertise in scientific practice or "the notion of accepting the knowledge that the public brings to the table in a discussion around science and technology and its implications to society in a way that didn't seem to be present in the public understanding model."

Conclusions

Science museums and leaders who promote ISE institutions as places to intervene in the politics of science are at odds with the ISE field's view of their institutions as neutral places of learning. The conception that museums and the work contained within them are neutral hampers the work of practitioners (and ISE leaders) who recognize the museum as a place of authority, power, and potential to impact citizens, communities, and the technologies that they shape.

Adult education is a necessary component of the future of museums, but while museums are not yet visibly political, the power of that education and the learning it produces will be filled with the mixed messages of the museum as a play-place for children and the museum as a neutral provider of information. Deliberative dialogue methods are a way to recognize the politics of science. However, this chapter demonstrates that this model was compartmentalized to *NanoForums* in the first five years of the NISE Network, because even the Network organizers were in disagreement as to the role science museums have in politics.

CHAPTER 5

CONCLUSIONS

The NISE Network and its relationship with the National Science Foundation played a significant role in defining the type of learning and educational approaches to emerging technologies that were trusted by the field of informal science education at large. The challenge of an unfamiliar subject, nanotechnologies, and unfamiliar methods, networking, distribution, and evaluation, shaped the Network's approaches to education and learning. Even when the Network was aware of larger trends in the field, like infusing issues of science and society into all learning activities, the challenges of building a network that stretched throughout the United States with professionals who had little experience with a content area such as nanotechnology, heavily shaped what and how the NISE Network prioritized its work in the first five years of its cooperative agreement with NSF. The three case studies of this dissertation demonstrate the compromises and negotiations the Network made in order to fulfill its obligations to NSF while managing the challenges of those obligations. Chapter 2 concludes that although ISE as a whole has interest in and utility for art methodologies applied to science education, ISE, as defined by the NSF, has not yet settled on the best way to incorporate such methods and knowledges into their practices. Chapter 3 demonstrates the constraints of spreading knowledge through a diversified, but professionalized network of informal science educators. The historical legacy of the field of ISE situates it within specific expectations and practices which shaped individual interpretations and assumptions about the best methods to use for a new topic. In many ways *NanoDays* could have been an opportunity to spread new knowledge throughout the network, but instead, it became an example of spreading previously established knowledge and practices about a new content area. Chapter 4 further identifies that which is currently being negotiated in the field of informal science education by looking at how professional practices and civic epistemologies play a role in defining the role of the science museum and the field in civic education and democratic society.

Evaluation

The struggles by the Exploratorium's Visualization Laboratory to contribute its knowledge, expertise, and physical deliverables to the Network demonstrate in Chapter 2 some of these important tensions in the field of ISE. Through its ISE program (recently renamed Advancing Informal STEM Learning or AISL), the NSF has had a significant impact on defining the ISE field. As David Ucko has written in an article from 2010 titled "Running Head: NSF Influence on the Field of Informal Science Education," AISL's

> [prior to 2010] performance measures [also referred to as program metrics] were based on such outcomes as levels of audience interest, attentiveness, and understanding and the percent or number of participants who gain knowledge, are excited by a topic, acquire skills, and take an action based on exhibits, media, and community programs.
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> In contrast, the program metrics submitted with the NSF fiscal year 2011 budget request (National Science Foundation, 2010), are based on the number of professionals who use ISE-funded resources to improve their knowledge and/or practice and the percent of development-intensive projects that employ appropriate

> evaluation methods and apply them with appropriate rigor.[273]

The Visualization Laboratory and the NISE Network did not find a shared interpretation of these "performance measures." In other words, the NSF's definition of ISE and the definition held by many at the Exploratorium did not fully overlap.

Although art methods are of interest to science museums and centers as a means of approaching informal science education in general (a quick look at any recent ASTC Annual Meeting Program's multiple sessions on art and science shows the field's interest in these issues), the NSF's definition of informal science education has made the inclusion of those methods difficult for the ISE professionals who depend primarily on its funding. The work the Viz Lab was most interested in pursuing (experiential, immersive events) was not the work that the Network organizers thought they would be able to distribute to and evaluate for the greater ISE community. These organizers were unable to conceive of a way to measure whether "outcomes" like those in the Ucko quote above were achieved by the kinds of events that the Viz Lab wished to produce and were discouraged by the difficulty of distributing such events. However, the deliverables that the Network organizers did encourage the Viz Lab to produce (scale ladders and zooms) did not include the alternative approaches to learning that the larger ISE field found exciting and interesting about applying art methods to science education. In effect the role of the

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[273] David Ucko, "NSF Influence on the Field of Informal Science Education" (presented at the 83rd Annual International Conference of the National Association for Research in Science Teaching, Philadelphia, PA, 2010), 14–15, http://caise.insci.org/uploads/docs/Ucko_%20NSFInfluenceonISE.pdf.

Exploratorium in the NISE Network was bounded by, on one side, the priorities of the cooperative agreement and, on the other, by the expectations of the field at large in relation to using art methods in science education.

The Exploratorium has long held a definition of ISE in which measured outcomes were thought of as only one aspect of the many approaches to the right kind of ISE. In addition, the work practices of the institution reflect an acknowledgement of the equivalent value of different approaches to knowledge creation. Although the methods have altered over time, the founding of the Exploratorium as a way to allow multiple types of expertise (artistic, scientific, experiential, etc.) to contribute to the creation of technoscientific knowledge and understanding within the institution's walls continues to be pursued (even despite the watering down of the philosophy that accompanied the spread of their techniques to which historian Hilde Hein has referred).[274] The Exploratorium today is, of course, subject to the same critiques as most other science museums and centers, but, when it comes to acknowledging the equal place of art and science educational methodologies, it has a stronger base than most. The skills the Exploratorium may have been lacking were more related to networking with other museums. In many ways the Exploratorium is accustomed to distributing the knowledge it has produced through its cookbooks or later through its Center for Informal Learning and Schools (CILS), but it may be less accustomed to distributing fully packaged exhibits and programs with their associated research and evaluation.

Distribution

[274] Hein, *The Exploratorium*.

Even if the NSF's yearly budget requests only began to use "metrics…based on the number of professionals who use ISE-funded resources to improve their knowledge and/or practice and the percent of development-intensive projects that employ appropriate evaluation methods and apply them with appropriate rigor" in 2011, these goals were already central to the initial program solicitation that led to the creation of the NISE Network. The Network's cooperative agreement, which began in 2005, required the partner institutions to engage in such "development-intensive projects," distributing them throughout the United States. With no exhibitions having been distributed by the NISE Network as of 2007, the organizers were under pressure to produce deliverables that combined multiple types of museum knowledge (practices, materials, evaluations, content) and quickly get them into a wide variety of ISE institutions.

NanoDays, with its inexpensively materialized knowledge, compact table-top exhibits, and accompanying "how to" guides meant to overcome the difficulties that educators inexperienced in the presentation of nanoscience might encounter, proved a convenient way to swiftly demonstrate the Network's fulfillment of the NSF's distribution requirements. *NanoDays* also serves as a contrast to some of the challenges faced by the Visualization Laboratory. Because the *NanoDays* kits were supposed to "employ appropriate evaluation methods and apply them with appropriate rigor," the table-top exhibits focused on content that museums and centers could convey in a way that the Network would know how to measure. But this need for clear-cut evaluative metrics excluded, in turn, any serious focus on issues of science and society related to nanotechnology. Since the ISE professionals involved in

NanoDays were accustomed to questioning visitors in a way that focused on whether visitors retained specific scientific facts, their deliverables presented the chemical and physical behavior of nanoscale materials rather than attempting to engage visitors in the process of critically thinking about how their own values, needs, and desires could shape the future direction of nanotechnologies. Contrasting these approaches makes apparent the tension between the different goals of ISE, especially when approaching emerging technologies. *NanoDays* kits' valuation of clear-cut learning goals as an approach to an emerging technology continued the expectation that the types of learning goals associated with the physical and chemical characteristics of a science were the most important aspect of the technoscience to convey. More open-ended learning objectives were prioritized below "facts" about the science. Nanotechnology, as an emerging technology, did, in fact challenge the field's competencies, but the response to that challenge was to rely on the skills, knowledge, and practices which the field had built and then relied upon for many years.

During the first five years of the Network, the challenge of incorporating a topic unfamiliar to the field into the field's repertoire using altogether new methods was met by the creation of *NanoForums,* not *NanoDays*. Thinking critically was one such approach. It is listed as one of the thirteen NISE Net "Forum benefits" in the *Forums Manual*.[275] Although an interest in nanotechnology's relationship to society and visitors' capacity to contribute to that relationship was compartmentalized into

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[275] Brad Herring, ed., "The NISE Network Public Forums Manual" (Museum of Life and Science, Durham, NC for the NanoScale Informal Science Education Network, 2007), 8.

NanoForums during the first five years of the Network, the work of the *NanoForums* team, not just in the making of the forums, but in thinking about the role of ISE and museums in the politics of science, has served as a platform from which the NISE Network could pursue incorporating issues of science and society into the Network and therefore the field as a whole.

A Place for Civic Education

Given the complexities of renegotiating the role of the museum and science center with a community of practitioners historically dedicated to maintaining the institutions as "neutral places," the efforts of those practitioners in the NISE Network dedicated "to provid[ing] experiences where adults and teenagers from a broad range of backgrounds can engage in discussion, dialogue, and deliberation, …enhancing the participants' understanding of nanoscale science, technology and engineering and its potential impact on the participants' lives, society, and the environment" were not immediately accepted by the Network organizers.[276] It is through the development of programs and their associated practices like *NanoForums* where it is made evident that "what counts as informal science education" is in flux; it includes *both* approaches to "knowing the facts" *and* "engag[ing] in discussion [to] enhance understanding."

In the last two years, for instance, through *Nano mini-exhibitions*,[277] a reorganization of leadership within the NISE Network, and the planning and implementation of "Science and Society" workshops in the fall of 2012 in

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[276] Ibid., 7.
[277] "Nano Mini-Exhibition | NISE Network", n.d., http://www.nisenet.org/catalog/exhibits/nano_mini-exhibition.

collaboration with the Center for Nanotechnology in Society (CNS) researchers at Arizona State University, the NISE Network is acquiring the capacity to equip these educators, historically dedicated to presenting strictly factual science, with the skills necessary to discuss and negotiate with their visitors about topics directly related to science *in* society (as opposed to societal implications of nanotechnologies). It remains to be seen what impact the NISE Network's activity in years five through ten of its cooperative agreement will have on the ISE field as a whole. However, given that even the NISE Network, which struggled to figure out how to negotiate the role of museums in the politics of science, has now begun equipping itself and its associates with the skills to directly address that role with visitors, even after the network ends, enough momentum may have been built for the field to begin considering the social role of science in all of its institutions' efforts.

Implications of this case for Science & Technology Studies and Future Research

The work of this dissertation begins to touch upon the role of scientific knowledge creation in defining and producing democracy. The case studies point to the role institutions of informal science education play in civic education and learning and the potential for that learning to contribute to civic power, authority, and the ability of educators and visitors alike to contribute to contemporary governance. The work that is focused on most closely here is the work of educators. More work needs to be done on the relationship between civic science education and institutions of informal learning and democracy. If in fact science is undergoing a process of democratization, what does that mean for the role of scientific knowledge in society?

Is scientific knowledge, broadly construed, a necessary component of democracy? If so, whose scientific knowledge?

A complex aspect of this dissertation's argument rests on the relationship among education, learning, and knowledge creation (and democracy). For example, we can argue that in an election, like the 2012 United States presidential election, the counting of ballots allows us to know who preferred Obama to Romney. However, we could also argue that the socio-technical system of voting in this country is merely making visible public knowledge about who should be the president, knowledge that we validate as authoritative and meaningful through the voting process. In this interpretation, the counting of votes is also a way of making visible individual's interpretations and "learning" about the individual candidates and the anticipated performances of those candidates. The "knowledge" that is created is our understanding of who prefers one person more than another. In this interpretation, the socio-technical apparatuses that enable people to feel comfortable making that choice, or even that motivate them to go to the polls, also requires the creation of knowledge and the ability of that knowledge to be verified or prove valuable to voters? In other words, what part do those sociotechnical apparatuses (everything from socio-economic standing, family norms, television broadcasts, social media, political advertisements and personal experiences) that provide information, knowledge, or impetus to vote play in the voters' creation of our knowledge about who won the election? Is the equivalent of voting in ISE individual choices to become a scientist, to support the scientific enterprise financially, or to support and contribute to a world in which science and technology can exist? Career choices, finances, and broader community support are all aspects of culture, without which “science” cannot continue, as it is embedded within that culture.

What role then, does a concept of “public knowledge” play in understanding where knowledge finds its authority and what role individuals and social groups play in constructing that authority? For John Ziman “science IS public knowledge.”[278] That does not necessarily mean other types of knowledge cannot be public, but it may in fact mean that “non” public knowledge cannot be scientific. If that is the case, then informal science educators and the institutions of which they are a part must be part of the process of creating scientific knowledge, as their number one objective is to successfully make scientific knowledge public.

Perhaps though there is a difference between “making scientific knowledge public” and “making scientific knowledge *for* the public.” If this is the case, then it seems that a tension arises if we try to equate scientific knowledge *with* “scientific knowledge for the public.” For the purposes of this study, I argue that making judgments about the validity of “scientific knowledge” (or its authenticity) by asking whether it is “altered” when made public, is in fact not a valid question, as it assumes an essentialism to the definition of science that is not borne out by what we know of the processes through which scientific knowledge is created. Context matters. History matters. Temporality matters. All of these factors, and many more, play a role in constructing scientific knowledge, with or without a laboratory or a field site. Nevertheless, more should be said about the power and authority of “public

[278] J. M. Ziman, *Public Knowledge: An Essay Concerning the Social Dimension of Science* (CUP Archive, 1968), 8.

knowledge," the pathways through which scientific knowledge becomes public knowledge, and the role that knowledge then plays in legitimizing or delegitimizing civic authority.

One way to do this may be to further delineate our current definition of "public knowledge." In Michael and Irwin's *Science Social Theory and Public Knowledge,* the authors' definition seems to be in relation to a deficit model of public understanding. They say that "public knowledge equals public understanding."[279] If we look beyond this simple definition toward the avenues through which public knowledge moves, is validated, and valued as "authoritative public knowledge," then having value beyond the public means having value for all publics be them scientific or nonscientific. This may give less powerful publics more authority within certain social arenas or institutions. A recognition of our "publics' knowledges" might move the focus away from an interest in a consensus toward more awareness of how certain knowledges have more or less power and importance in certain contexts. "Public knowledges" then, in effect, open up the possibility for different types of scientific knowledge. These tensions all need to be further examined in relation to the role ISE plays in defining, characterizing, and creating scientific knowledge.

Perhaps another way of examining the role of ISE in defining knowledge about an emerging technology like nanotechnology is to think about ISE actions in relation to building citizens' civic capacity to better anticipate future scenarios with nanotechnologies. Other scholars have looked at the implications of building the

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[279] Mike Michael and Alan Irwin, *Science, Social Theory and Public Knowledge* (Open University Press, 2003), 51.

capacities of citizens as scientists[280] or building the capacities of engineers through developing their ethical conscience[281], but for my purposes it may be worthwhile to examine the role ISE contributes to the civic capacities of educators and visitors in relation to the anticipatory governance of emerging technologies.

For Barben et al., anticipatory governance

> comprises the ability of a variety of lay and expert stakeholders, both individually and through an array of feedback mechanisms, to collectively imagine, critique, and thereby shape the issues presented by emerging' technologies before they become reified in particular ways. Anticipatory governance evokes a distributed capacity for learning and interaction stimulated into present action by reflection on imagined present and future sociotechnical outcomes. [282]

In light of this definition, if the NISE Network was put into place to develop "awareness, understanding and engagement" and in response to what the scientific community perceived as unwanted, negative outcomes of the visibility of GMOs in Europe, then perhaps thinking of ISE approaches to emerging technology as necessitating an acknowledgement of science in society or science and society is not so radical. The case studies of this dissertation merely bear out how the leaders of ISE who have been promoting contemporary science and technology are building the capacity of the field of ISE to play an important role in shaping "imagined present and future sociotechnical outcomes." In addition, although how you build and define that

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[280] M. Kearnes, "Governing at the Nanoscale: People, Policies and Emerging Technologies", 2006, 200, demos.co.uk.
[281] R.a.J.S. Berne, "Teaching Societal and Ethical Implications of Nanotechnology to Engineering Students," *Bulletin of Science Technology & Society* 25, no. 6 (2005): 459–468.
[282] Barben et al., "38 Anticipatory Governance of Nanotechnology," 992 and 993.

capacity seems to be in flux, as evidenced by the tensions surrounding what is evidenced as "learning" or what evidence counts as learning, this dissertation nevertheless portrays a method of building such capacity. What perhaps should further be examined in relation to capacity building is the role social scientist researchers, working in this area, are playing in influencing the kinds of capacities built in the field of ISE.

In the NISE Network, (1) who gets to have the authority to create scientific knowledge and (2) what are the implications for science, education, and democracy in the answer to who has the authority to speak for and about science can be better understand in relation to different types of boundary and the tensions that arise in each. For the purposes of simplicity I focus on two of Thomas Gieryn's four types of boundary work (monopolization, expansion, expulsion, and protection) in relation to my study.[283] Monopolization is:

> …where contending parties carve up in the intellectual landscape in discrepant ways, each attaching authority and authenticity to claims and practices of the space in which they also locate themselves, while denying it to those placed outside.."[284]

Monopolization is complex in my study as I found educators attaching authority and authenticity to what they do by *denying* that *they* are part of a particular space (making scientific knowledge). Instead, they claim to serve as securers of that space from the outside. In effect, when these educators located their authority in the act of relaying

[283] Thomas F. Gieryn, "Boundaries of Science," in *Handbook of Science and Technology Studies*, ed. Sheila Jasanoff et al. (SAGE, 2001).
[284] Ibid., 424.

"the facts of science" they deliberately constructed a boundary between what they do and what scientists do. My study reveals that through this interpretation, rather than supporting the space, claims, and practices inside which science is made, these educators actually circumscribe an entirely different space of scientific authority. In other words, they inadvertently set themselves AND scientists outside of the sacred space they profess to protect, thus developing a definition of science and scientific authority that seems to be completely separate from all cultural and social influence, including the scientific.[285]

Expansion is

> …when insiders seek to push out the frontiers of their cultural authority into spaces already claimed by others.[286]

This type of boundary work reveals the tensions and power associated with scientific and artistic authority. Scientists like Eric Heller see themselves qualified to claim the cultural authority of art because of their scientific authority. Heller seeks to be interpreted as having scientific AND artistic authority. The Materials Research Society also sees itself as propagating the authority of scientists to demonstrate the power and authority of art, especially art about science. Perhaps the most interesting example of this sort of boundary expansion is the work done by those most interested in the museums' place in politics, particularly the politics of science: institutional leaders. When ISE and field leaders insist upon the space of the museum as an

[285] When educators disembody science from the makers of it and the context in which it is derived, they also set scientists outside of the space.
[286] Gieryn, "Boundaries of Science," 429.

important location for building citizens' civic capacities to negotiate their technoscientific worlds, and in addition insist that the institution is not only a site but a source of scientific knowledge embedded in its cultural landscape, they are claiming the space already occupied by secondary science education in the United States as well as by many scientists.

Challenges of Methodologies

The greatest challenge to this study was managing access to resources and interpretation of different types of evidence. Attempting to study a network whose participants are scattered throughout the United States, and who only seldom meet face-to-face, challenges the ability of an analyst to be a participant-observer. In addition, the three case studies examined in this study all rely upon different types of source materials. What is the best way to study something that never fully came to fruition? At the Exploratorium, partly due to my timing as a researcher and partly due to the role the Exploratorium did and did not play in the Network, I found myself piecing together a story based on oral accounts and online databases, documenting what did happen, but not necessarily what had been hoped to have happened. I tried to carefully place into context why the early plans of the Network, as laid out in the original proposal to the NSF and in the Annual Reports to NSF of Year 1 and Year 2, did not match the work I was observing in Year 3 and Year 4. This is not unusual with a project as large and unwieldy as the one produced by this cooperative agreement; but most large projects do not have someone combing back through their files and wondering what happened to various aspects of a proposal. In my case, partly because there was also a reasonable degree of turnover of personnel within the

Network, I relied most heavily on interviews with the Principal Investigators and other organizing members of the NISE Network, who had been around since the beginning of the Network in 2005. This challenged my abilities to document the work at a place like the Exploratorium, where the project was winding down just as I was beginning my study. I did not want to place intent, or lack there of, where there was no or little reliable evidence. However, I know that as individuals referenced the same complaint or the same event, off the record, repeatedly, their thoughts and perspectives influenced my approach to the close readings I conducted of the online databases, for instance.

Some methodological approaches did hold steady across the three main cases. In particular, the NISE Network's online catalog proved to be an ever-changing, ever-growing resource to track changes over time within the Network. By capturing earlier iterations of the website, I was able to conduct close readings of the online material located in this database. This allowed me to track the changes in the Network's public face. For instance, changes in vocabulary associated with working group names, reflect, though not in real time of course, changes in Network priorities, approaches, and understandings of topics like "social and ethical implications" as opposed to "science and society." The contemporary nature of this project made it both daunting and exciting. I hope that I have been fair in my assessments of the materials that were made available to me.

Finally, I frequently refer to the National Science Foundation and to the "network approach" without trying to pull apart in great detail who is represented by the NSF or what in detail that "network approach" entails. Two important points became clear to me early on in my research for this dissertation. First: the National Science Foundation has heavily influenced the definition of ISE in the United States and that influence has not been fully documented. In addition, my focus on educators as the primary resource for this dissertation was only going to indirectly shed light on the NSF influence. As this research continues, I plan to address this role explicitly through oral interviews of all of the program officers responsible for the NISE Network, in addition to archival analysis of the various important policy initiatives associated with ISE and the NSF.

Second: the network as a point of analysis could have made up the entirety of this dissertation. Although it was obvious from the beginning that questions about the role a network model played in shaping the definition of ISE for the NISE Network were entirely relevant, I decided explicitly not to pursue this approach. In doing so, I felt that I was able to point out the most important moments in which the network model heavily shaped approaches within the NISE Network, but I avoided giving the network model more agency than it perhaps deserved. As is made obvious by references by the NSF staff and documents as well as by practitioners in my study, the network requirement was influential. However, it was only one aspect of many others that shaped the approaches of the NISE Network. I chose deliberately to try to cull all of the major influences mentioned by the sources in this dissertation to attempt to document how the practitioners themselves made sense of the messiness within which they worked. Approaching the network model directly would have hidden some of the other major challenges and tensions that arose organically, as I tried to understand knowledge-making materialized in such things as informal and formal professional development sessions, exhibit and programming plans, conference calls, evaluation and assessment research, and approaches to distribution.

ISE in transition

At the time of this research and writing, the definition of informal science education was in transition. It may be fairer to say that ISE has always been in transition; however, with the recently concentrated interest by influential institutions, professional societies, and funding organizations in the role ISE plays in the civic capacities of visitors to engage with science and technology, space has been made for the more intransigent priorities, practices, and ideologies of ISE to be challenged. This case study demonstrates how nanotechnology provided an opportunity to open up that space of contestation and redefinition of ISE.

The original urgency behind the NISE Network collaborative agreement reflected an acknowledgement that when science and technology is currently emerging, its future potential and value for society is also emerging. That value is much more volatile during these still early stages, as evidenced by, for instance, the EU's rejection of genetically modified organisms. Nanotechnology also has the added bonus of being associated with high impact. The potential, whether or not rhetorical, of the future impacts of nanotechnologies made it a good site to pursue a new agenda and new approaches associated with an emerging technologies in informal science education.

In addition, the supporters and designers of the cooperative agreement saw ISE as more flexible and adaptable than secondary education in the United States. Ordinarily, change happens slowly, as ideas and practices spread between professional meetings and papers to institutional mandates and expectations. However, the network model demonstrates that the NISE Network was believed to be able to speed up the ordinarily glacial and idiosyncratic pace of change in civic education, to institutionalize new approaches, programming, and expectations about how to use the resources of ISE to address emerging technologies in civic life. That the topic was nanotechnologies, as mentioned by David Ucko, allowed for the enrollment and support of the scientific community and made the funding possible.

These institutionalized changes which emerged from the NISE Network and have been taken up by the field and vice versa, occurred via a process of knowledge creation. Knowledge creation in this case study involves the reification of ideologies, practices, and definitions of science and technology. In some cases, leaders of ISE published, gave speeches, changed institutional mandates and mission statements, and provided financial resources to ensure that their ideas about the definition of science and who gets to play a role in that definition physically materialized in exhibitions, programming, and professional development initiatives. In other cases, members of the NISE Network selected out and selected for definitions of nanotechnologies that they felt best represented nanotechnology as a legitimate scientific practice. Over time, the Network began to recognize that the values of science and scientists were not the only values determining the most legitimate scientific knowledge. The values of educators and visitors also play a role determining legitimacy, use, and meaning of scientific knowledge, particularly emerging technoscience. This transition within the NISE Network demonstrates a transition – still just beginning – in the field as a whole.

A large portion of this dissertation tries to unpack the relationship between the museum as a site of learning and education, the development of the ISE field, representations of emerging technoscience, and democracy. Many argue that a shift is underway. Museums are readapting their purpose and place within society, particularly science museums' place in civic education. With emerging technologies, museums can open up places and resources of civic education and learning. In other words, by directly addressing and conjuring the museum space as a place for knowledge creation not wholly determined by scientific experts, the museum invites other voices, values, and approaches into the production of scientific knowledge. The space can be a place open to the community and its priorities as a way to respond to those interests and priorities and produce and shape what is important and what people should and can know. The "right kind of ISE" includes all of these approaches.

This dissertation demonstrates some of the tensions among focusing on current science, science-in-society, and societal implications within an ISE context. These are categories used by the actors of this study, but which represent the presence and relationship of these actors to other social groups and movements. These are tenable categories only so much as it is recognized that these categories are a way of opening up for other groups alternative approaches to the definition of science. The Center for Nanotechnology in Society at Arizona State University, who has been the most influential group of social scientists to collaborate with the NISE Network, uses the language of science-in-society to try to recognize the co-production of these concepts as well as the factors that play into this co-production. Rather than thinking about science in society as a binary system of risks and benefits, the term science-in-society is a way to think about science as one part of society, with many other factors that shape interpretations, understanding, and uses within society. In addition, if the project that is underway is a democratization of science, in other words, a move towards not just recognizing (which has already happened) but to systematically integrating the knowledge and expertise of nonscientific experts into the definition, uses, and regulations surrounding science and technology, informal science education is a place for this to occur. With the recognized crisis of secondary education in this country, there is an opportunity within spaces of informal learning to more fully develop citizens' capacities to negotiate emerging technologies.[287]

This dissertation begins to add to a definition and process of democratizing science in which ISE plays a pivotal role. This is a two part process. Part one involves the relationship of science educators with science experts. When the authority of ISE is recognized as having valid place in the construction of scientific knowledge, what counts as science is expanded to include a wider array of perspectives and values. When the institutions of ISE are recognized as not just having the authority to produce valid scientific knowledge, but as a necessary component to including a wider array of perspectives and values in the production of scientific knowledge, then better civic education and more successful democracy is possible. In this way the definition of scientific expertise is also expanded. Part two involves the characteristics of ISE that make it a space more responsive to including, incorporating,

[287] D. Barben et al., "Anticipatory Governance of Nanotechnology: Foresight, Engagement, and Integration," *The Handbook of Science and Technology Studies* (2007): 979.

recognizing, and validating nonexpert voices and perspectives in the project of scientific knowledge creation. For emerging technologies, if educators are included as valid sources of knowledge construction then citizens are included as well, even when there is not a crisis. A crisis does not need to develop for citizens to have greater access and abilities to shape science and technology in the making.

How do informal science educators contribute to scientific knowledge-making? The most obvious way is through the materialization of exhibits and programs. The exhibits and programs are only the last stage of this knowledge-making, however. These exhibits and programs are the product of a cascade of planning documents, publications, instructional manuals, professional development workshops and meetings, evaluations, and professional presentations and conferences. They reflect the best methods of learning about science and technology for educators and visitors alike, propagating the ISE field's educational priorities, institutional allegiances, and professional values. Shaping more than their publics' basic knowledge of scientific phenomena, scientific methods, or scientific thinking, informal science educators' intellectual and material work shapes individuals' expectations of science and technology. Developing publics' capacities to more fully engage in their civic lives through a more complex understanding of their relationship to science and technology makes the regulation, use, and interpretation of science and technology the purview of more than just technocratic experts. That developmental work, and the knowledge made available to citizens through it, demonstrates the important role educators play in democratizing science and technology.

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