DragonflyTV: *Investigating the Nanoworld*

Summative Evaluation Report

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I. Introduction

The Need

In recent years academic, engineering, business, and other fields, have launched major research and development efforts into the study and application of nanoscale science, engineering, and technology. "Advances in nano… are revolutionizing medicine, computing, materials science, energy production, and manufacturing."[1] Nanoscale science and technology research centers, institutes, and university departments have sprung up across the country and around the world in large numbers.[2] These efforts are being funded by organizations ranging from the National Science Foundation, to the Pew Charitable Trusts, to the Woodrow Wilson International Center for Scholars, to many other foundations and governments.

In spite of all these efforts and the investment of millions of dollars, the general public has had little access to research findings and knowledge about the application of nanoscience and technology. Several studies have been conducted in recent years to assess public knowledge and understanding; they show that a large percentage of the public is not aware of this emerging field (as compared with other fields such as genetic engineering and stem cell research). In particular, studies have found that nanoscale science and technology, due to its highly abstract nature, is especially inaccessible to younger audiences.[3] Additionally, there is some evidence that the public has a mistrust of nanoscience and—although often misinformed—they have doubts and fears about the nature and potential of this emerging science and its possible risks.

[1] "Welcome to the NISE Network." Retrieved February 17, 2009, http://www.nisenet.org/about.
[2] According to the NISE Network there are 231 organizations listed as "partner" institutions.
[3] Waldron, A., Spencer, D., Batt, C. Current State of Public Understanding of Nanotechnology. *Journal of Nanoparticle Research*, Volume 8, #5, Oct. 2006.

The Context for This Project

The DragonflyTV series produced by Twin Cities Public Television (TPT) in Minneapolis/St. Paul, Minnesota, has a solid reputation for providing science education television for children ages 9-12. The series follows a tradition of portraying "real kids doing real science" through filming children's investigations of a science or technology question or phenomenon that is of interest to them. DFTV has operated under the assumption that—by presenting real children engaged in their own science inquiries and by portraying science and scientists as cool, upbeat, engaging, and relevant—the series will "model authentic explorations of science," so that children watching at home will think: "I can do science too!"

The 14 episodes of DFTV entitled GPS (Going Places in Science),[4] originally broadcast over two seasons, are based at science museums, where "typical" kids are shown beginning their investigations into some form of phenomenon in the museum exhibits or interactive programs. The show then follows the kids as they continue to investigate that phenomenon in the "real world" (outside museum and school settings).

After considerable research into what resources are currently available in nanoscience education, and seeing the need to familiarize children with this emerging science, the science and technology division of TPT proposed to the National Science Foundation that they create a set of DragonflyTV programs specifically focused on the topic of nanoscience.

DFTV GPS: Investigating the Nanoworld

With the DFTV Nano series,[5] TPT proposed that they could meet the need to make nanoscience education accessible to children by producing televisions shows that draw upon the unique assets and opportunities of television, museums, and research institutions. They felt that by engaging kids with real phenomena in a science center context, having children explore those phenomena more deeply via interactions with scientists, and capturing all of this in a television format, they could make nanoscience engaging and accessible for young viewers. TPT hoped that their targeted viewers (the children with their families) would then begin to explore science further by accessing the games, experiments, and other resources available online.[6] DFTV GPS: *Investigating the Nanoworld* is shown on more than 70% of the 350 PBS channels across the country; the segments can also be viewed online at pbskids.org.

[4] See http://pbskids.org/dragonflytv/parentsteachers/gps.html.
[5] In this report, we use the shorthand "DFTV Nano" interchangeably with the *Investigating the Nanoworld* title of this series.
[6] See http://www.dftvpress.org/index.html.

DRAWING ON CURRENT PRACTICE AND NANOSCIENCE EDUCATION COMMUNITIES

The *Investigating the Nanoworld* project was funded by NSF to explore ways to engage the public in nanoscience and technology. As part of their philosophy and following their usual approach to television production, the DFTV/TPT team spent time strategically and carefully nurturing long-term relationships with the key players to be involved in the production—the museums, scientists, educators, and other media groups. Through the *Investigating the Nanoworld* series, the DFTV team sought to find ways to leverage the strengths of public television, in collaboration with the expertise and resources of science museums and research scientists, to create a well-integrated and coherent resource for children's introduction to nanoscience and technology.

The TPT staff, as media partners in the NISE (Nanoscale Informal Science Education) Network,[7] invested a substantial amount of time attending NISE workshops and meetings, gaining knowledge and cultivating relationships that resulted in the production of the DFTV Nano series. TPT also drew on partnerships with the outreach and education specialists at research centers including the Materials Research Science and Engineering Centers (MRSEC), Nanoscale Science and Engineering Centers (NSEC), the National Nanotechnology Infrastructure Network (NNIN), and the Nanotechnology Center for Learning and Teaching (NCLT).

[7] See the Nanoscale Informal Science Education Network at: http://www.nisenet.org.

II. The Evaluation

Background on Our Study

Inverness Research was contracted by TPT to conduct one part of a summative evaluation of the DTFV Nano project. In particular, we were asked to study the three-way collaboration between museum and scientist partners and the DFTV staff, and to document the nature, qualities, challenges, and successes of this relationship. This focus was deemed important by both the project team and our evaluation team based on the assumption that a collaboration like this is not only potentially valuable, but perhaps even necessary in order to create a production that could enhance public opinion and education in nanoscience and technology. The project proposed that none of the institutions involved had, on its own, the capacity to achieve this agenda; however, by working together they could address this important goal—one that they all shared.

The larger goal of the summative evaluation was to distill lessons from this production that might inform the design of future efforts that require collaboration across fields and educational domains. Initially, we focused on the research questions below, as we identified key issues and strengths of the collaboration, and as well as strategies germane to other comparable partnerships between media producers, museums, and scientists:

- How did the partners in this collaboration perceive their commonalities and differences, and to what extent and in what ways did they appreciate the interactions between representatives from the worlds of television production and those of education?

- How, if at all, did the partners' attitudes regarding the value and potential of this collaboration specifically, and of media/museum collaborations more generally, change over the course of the project?

- To what extent and in what ways does the three-way collaborative effort of *Investigating the Nanoworld* contribute to innovative presentations of nanoscale science and technology? What, if anything, can be accomplished and produced in a collaborative format that could not be accomplished without it?

Methodology

- We conducted baseline and follow-up phone interviews with 18 people at 10 institutions[8]. These interviewees included directors, educators, and public relations staff at partner museums, as well as science research partners.

[8] See Appendix A for a complete listing of those we interviewed at institutions.

- We conducted eight phone interviews with TPT staff and contractors hired for the production.[9]

- We interviewed Richard Hudson, the project's principal investigator.

- We interviewed Barbara Flagg, the project's formative evaluator.

This Report

This report is a summary of findings from our study of the collaboration that went into producing DFTV GPS: *Investigating the Nanoworld*. The audience for this report includes:

- The National Science Foundation (NSF) and other funders (particularly science research funders)
  This report describes an effective model for producing resources that can communicate emerging science research to the public, and in particular to younger audiences. It details an approach that optimizes the expertise and particular advantages of specific science and education domains (public television, science museums, and science research) to provide access to abstract, complex, cutting-edge or emerging science research.

- The informal science education field
  This report details the design features of a collaborative model that draws upon and services the expertise and repertoire of informal science education institutions. We include lessons learned about establishing these collaborations and the challenges inherent within. This report will be of interest to informal science education institutions that might be considering collaborations, particularly those that involve science television production and/or science research at universities.

- The leadership and staff of DFTV at Twin Cities Public Television
  This report provides feedback to the leadership and production teams at TPT regarding the perceived benefits and challenges of this collaboration.

[9] See Appendix A for a complete listing of those we interviewed at TPT.

The report is organized into the following sections:

I. Introduction

II. The Evaluation

III. The DragonflyTV Model

IV. Benefits of This Collaboration

V. Challenges and Lessons Learned

VI. Summary

III. The DragonflyTV Model

In this section of our report, we discuss the DragonflyTV production model as a tool for informal science education. We describe the original production model, the ways in which the model shifted for the nano series, and the ways in which each collaborative partner contributed to the model. The purpose of this section is to provide the reader with a context for lessons learned about the DFTV Nano partnerships.

The Traditional DFTV Model

The production model that DFTV has traditionally adhered to for the Emmy® Award-winning program is designed to inspire and excite kids to investigate their own questions about phenomena they have observed around them, and to make science fun for children. DragonflyTV is designed to encourage young viewers from a wide range of socioeconomic, ethnic, and educational backgrounds to engage in science and the process of scientific inquiry. The idea is to present "real kids doing real science." When asked to describe the general DFTV model, one producer said:

> *The goal of DFTV as an entity is all about getting kids interested in science. Getting kids to think about science in an investigative way, asking questions, and to model a way of thinking that is unique to science and the scientific process.*[10]

The traditional DFTV format involves a focus on children's personal stories, with children asking their own questions about their environment and figuring out ways to investigate their questions. Another producer described the model this way:

> *In general, it's trying to demonstrate to kids that science is fun and it's part of their world everyday, all the time. It's about introducing them to the investigative method, which is a fancy way of saying 'logically exploring questions' and 'what is a great way of finding things out?' The whole process is fun.*

Children collect their own data, analyze the data, present their analysis in some way, and then ask new questions, thereby engaging in a full cycle of inquiry. The format also incorporates the local community wherever possible. The traditional DFTV model can be contrasted with other science television models in that typically, DFTV child investigators do not simply go out and ask scientists for answers or rely on an adult presenter who gives the children science information. With DFTV, the children are empowered to do the investigations themselves and the presence of adults is minimized.

[10] The quotes in this report have been lightly edited for clarity without changing the intended meaning of the speaker.

The viewers' experience is enhanced with the supporting resources available on the DFTV interactive website, such as video podcasts, games, and publications. Viewers of the show are encouraged to duplicate the investigations with easily accessible materials. Each regular DFTV segment tackles a different subject and each segment can be viewed independently—i.e., they do not need to be seen in a particular order to be understood by the viewer.

The *Investigating the Nanoworld* Model for DFTV

Because of the emergent status of nanoscience and its fundamentally abstract nature, the *Investigating the Nanoworld* series deviated from the traditional DFTV model in several ways by necessity. With previous series, the focus of DFTV was primarily on inquiry and how to conduct an investigation by framing a good question and determining what one might do to study that question. With the *Nanoworld* series, TPT wanted to provide children and other viewers with access to an abstract and complex science. In order to do so, the *Nano* series combined the existing strengths and expertise of three milieus—informal science education, research science, and children's investigations—to provide that access. A producer described one difference between this and prior series:

> *The overall style of the series was the same—real kids doing real science—but the science is so cutting edge and new. People are just breaking the ice as to what nano is. Past episodes had more science that was clear-cut and simple—nano is less clear-cut in that way.*

At its core, this new series was designed to introduce children to nanoscience, which alone encompasses several different research areas and scientific disciplines. In order to provide a thorough overview, the segments are designed as a series, following a scope and sequence determined in advance (e.g., the first program in the series served as an introduction to the concepts of size and scale so that the second program could focus on the structure of matter). The series also employed a narrator who introduced the content, following a "host script" written by TPT staff, and conducted what one informal educator called "facilitated investigations." By necessity, overall, the *Investigating the Nanoworld* series reduced to some extent the focus on science *process* and children conducting hands-on investigations, and increased the focus on science *content*, as compared to previous series.

Below we describe the contributions that each DragonflyTV partner made to the model.

Research Scientists

In previous DFTV series, children were the sole or primary focus of the programs, and were able to conduct their own self-designed investigations—often outdoors, in their community, using everyday items. The new *Nanoworld* series required some work inside of laboratories, using highly specialized equipment, which in turn required the particular skill sets of researchers. To investigate the invisible nanoworld, DFTV sought to demonstrate

the use of the tools that scientists employ and, with the collaboration of the scientists, expose children to those tools and techniques. As a result, in the *Nanoworld* series, the children shared the focus of the program with research scientists.

When one producer was asked how including research scientists and universities helped serve the DFTV model for the *Investigating the Nanoworld* series, she replied:

> *I would use a stronger word than 'help'—in the sense that the nano series, by necessity, had to diverge from DFTV earlier principles. Usually the [series] was trying to show kids they could find out a lot by themselves, but in nano—in large part because of the invisibility of nano particles—we had to deal with research technology that was so far beyond kids' access and understanding. Without the research scientists, this show could not have been done. They could show how the research is being done and interact with scanning electron microscopes. It was a completely different ball game.*

Of the research scientists working on this series, the TPT Director of Science Production said:

> *They became such critical partners and they worked so hard. The scientists worked with us to make sure we could bring the kids in and explain and show things and try experiments. They went way beyond the call of duty to make this a success and we were thrilled with that.*

SCIENCE MUSEUMS

The challenge TPT faced when trying to figure out how children might do authentic inquiry around nanoscience was mediated to some degree by involving informal science—or museum—educators. Local museums and science centers provided knowledge and experience that was different from but complementary to the knowledge and expertise of either the television producers or the research scientists. Museum educators provided access to resources such as exhibits, materials, and interpersonal connections in the community. One DFTV staff member said of the museum staff:

> *They were the guides in the cities. Sometimes they had their own exhibits and materials, and they had a lot of connections with the university settings, with the scientists.*

Informal science educators have extensive experience making complex science accessible to children, and they have experience designing activities and exhibits that make visible what normally cannot be seen. Importantly, when one producer was asked how the content of nanoscience was different from previous DFTV topics, she responded plainly:

> *The simple answer is that it's invisible. That is, from every direction, the biggest difference. You just don't have as many visual examples…so you are constantly looking for analogies.*

Museums and science centers practice a tradition of finding visual analogies for the invisible. Science centers and museums also have a long history of designing inquiry-

oriented science processes and investigations for a varied audience. One goal of the *Investigating the Nanoworld* series was to highlight the rich resources available to the public through science museums. As the TPT Director of Science Production said:

> *There are these marvelous resources in the museum community and the model is to make the public more aware of those places they can go to do and find science.*

TWIN CITIES PUBLIC TELEVISION

While research scientists and science centers served the *Investigating the Nanoworld* model in new and different ways, so too did TPT. In terms of what TPT brought to the collaboration, the series producer said:

> *We brought new ideas to the table regarding how to represent nano…how to create visualizations.*

TPT offered technologies and formats that museums and research scientists did not have the expertise or the resources to produce, and the project partners appreciated this contribution:

> **Museum partner**: *There are some new technologies and some new techniques for reaching children and I think Dragonfly is one of them.*
>
> **Museum partner**: *Television is a great way to tackle subjects where the content is a bit more difficult, where you need to do more talking at the person before you can talk with them about the science. With nanotechnology you have so many things you have to teach them, like what the size scale is and what an atom is…there is a lot of ground that you have to cover before you get to the application. Since you have more time with a television program, it seems like a great venue for being able to dive in a little bit deeper to subjects that you don't have the luxury of doing in other media.*

Overall, the TPT / DFTV crew brought a high level of expertise and experience to all stages of the project, including planning and logistical expertise as well as techniques and new media to apply to content development and portrayal.

IV. Benefits of This Collaboration

The DFTV *Investigating the Nanoworld* project provided a range of benefits to collaborative participants, and produced a product that can be built on and used over time in a variety of contexts. In the end, this investment created a series of TV episodes that included introductory and core nanoscience and technology concepts in a child-centered format, and that framed the topic, the institutions and people in a positive and exciting way. Below we summarize the benefits accrued to the collaborative scientist partners, the museum partners, and to the field.

Benefits to Scientists

The *Investigating the Nanoworld* series provided scientists with opportunities to communicate their research to a mass audience of approximately 15 million children, adults and educators over the next ten years. These are audiences not traditionally accessed through universities' outreach efforts. Typically, the universities involved in educational outreach efforts tend to target either high school students (in an effort to draw potential students) or very young children in their demonstrations. This new DFTV series allowed the scientists another avenue to meet the "Broader Impacts" criteria of many of their own grants.

> *This project gets our university's name out there; it gives us exposure. We do a lot of summer exploration programs in materials science and school experiments, [but] it's good to get it out in this form. For me it was a nice change of pace, to show people what I do and what it's like to do science as a career. Usually people hear about the bad stuff…so we're reluctant to tell people [about the science]. It becomes an isolated community and it gets stale.*

In addition, the Director of Science Production at TPT described another benefit to scientists, as a result of their enthusiastic and thorough support:

> *We identified the NSF grant officers who were funding the scientists' research projects and made sure we sent a letter of thanks complementing this person on the contribution that they made to the series, because it was really extraordinary.*

Therefore, scientists' participation in this DFTV series served as positive public outreach for the scientists and their institutions, as well as an opportunity for them to communicate their research to previously untapped audiences.

This project highlighted informal science institutions, and their expertise in providing hands-on science education opportunities. It placed the museums in the national scene as part of the larger nano education effort, and as part of the children's public television forum. Additionally, it provided museums with a new medium for reaching their goals in terms of nano education. As one museum partner explained:

It was good for our exhibits and education departments to be involved with this project, to think of a way to involve kids in our programming that we maybe hadn't considered before. It raised the awareness of our staff of the different opportunities that might be out there.

Another benefit to museums is the expertise and content that they gain from collaborating with local scientists:

The importance of collaborating with scientists is just that: they are the real experts in this and we provide the ability to bring their research down to a more digestible piece… but they provide the validity…

All of the museum and science partners agreed that the project brought positive exposure to their institutions, and they expressed interest in maintaining a relationship with DFTV and in participating in future partnerships.

Museum partner: *The value of this collaboration for designing visitor experiences has been enormous. Trying to listen to [our visitors] more, what they need or want, rather than us thinking we know what they need is important. Collaborating with someone like DragonflyTV brings more validity to the project and more national attention. I can make something similar to what they made, but I may only get 1000 views on our website, so having the partnership with someone like them gets us more exposure.*

Museum partner: *I would like to see the collaboration continue and if there are any opportunities in the future, we would certainly be very excited to work with DFTV again. It is always fun to have someone else come in and show you your own institution again in a totally different light. At first we said, 'okay we will do something on nano' and then we realized we didn't have nano in the museum. It was interesting to see what DFTV came up with.*

Benefits to the Field

As we noted in the introduction, TPT has been in the science education television production business for many years. And science TV programs produced by other stations have been aired for decades. However, this DFTV series made particular contributions to the field of informal science education.

First, the series focuses on a relatively new topic—nanoscience and technology—that many members of the public have not been exposed to yet. This provides the field with a new asset for teaching about this important science. Project partners agreed that a significant outcome of this investment and the collaboration is the actual TV series itself, which provides an opportunity for young viewers across the country to become exposed to basic nanoscience and technology. They felt that the medium of television made accessible the more abstract nature of nano, and provided a context within which viewers might engage with the topic more extensively than in the museum setting. The group also felt that children and their families are more likely to view their local museums as a more in-depth resource than they may have in the past. Thus the series is likely to help both

informal and perhaps also formal educational institutions reach middle school-aged children in an engaging way.

This project also provides the field with an example of a model collaboration that demonstrates the specifics of how institutions of informal science education, research scientists, and television producers can—together—effectively tackle a challenging scientific topic and make it accessible to public audiences.

V. Challenges and Lessons Learned

As noted throughout this report, the DFTV *Investigating the Nanoworld* program combined the existing expertise and capacity of different groups (museums, research scientists, and television producers) to make nanoscience and technology accessible to young television viewers. Overall, the project was an efficient and powerful tool that resulted in opportunities to investigate and understand challenging, abstract science research.

While the DFTV *Investigating the Nanoworld* series was graced by the exceptional talents of its partners, the artfulness that was required to organize, mediate, coordinate, and maximize the wishes and expertise of these numerous partners should not be minimized. In fact, there were very clear challenges to the collaboration and the work. This section reviews the key lessons we learned about what is required to create a successful collaborative of this kind. They are organized in the following domains:

A clear sense of purpose

- Making accessible a complex scientific topic, while maintaining the core values of the institutions involved
- Science content

Appreciation of and respect for mutually beneficial relationships

- Clear and open communication
- Logistics and procedures
- Work style and pacing in museums and television production

Building on the capacity of experienced practitioners

A Clear Sense of Purpose

First and foremost, the partners involved in DFTV nano series shared a clear sense of purpose, and the purpose served the missions of each institution. While at times there may have been disagreements regarding which topics were most appropriate for which settings, overall, the partners agreed with the mission of this series: to make nanoscience accessible to younger audiences and to incorporate available local resources. Much of this mission was shared already due to the existence of the NISE Network and many partners' belief that, as the Director of Science Production said, "There really was a job to do—to communicate nano to younger audiences."

> *I think we are demonstrating that there is a great potential for overlap, that we can improve our [TPT] programs by drawing on the resources in the museums, and at the same time we can give the museums real promotional service, by putting the idea of going to a museum in the public's eye, when they turn on the TV set and [go] on the web…*

TPT's extensive experience with producing science television programs for children was key to keeping a clear sense of purpose and to the ultimate success of the *Investigating the Nanoworld* collaborative. When issues arose DFTV staff could rely on their previous successes to guide their decision-making. What follows are a series of concrete example of challenges related to collaboration and production—and how having a clear, experienced, and reputable leader alleviated difficulties that might have paralyzed a different production.

Making accessible a complex scientific topic while maintaining the core values of the institutions involved

This collaboration brought together multiple partners with different expertise and work cultures. The overall goal was to make nanoscience accessible to younger audiences. However, each partner also brought their own, somewhat overlapping agendas to the table. The museums wanted to highlight their institutions and associated research facilities, and make known the resources and experiences available to the public for becoming familiar with emerging science. The researchers wanted to communicate complicated science and share their work with a general audience, and to inspire young people to be interested in science as a potential career. DFTV wanted to produce a series that would provide an accessible, interesting introduction to nanoscience and technology, one that would enhance their GPS series that showcased "real kids doing real science." These agendas are not necessarily mutually exclusive. However, the range of interests to include in the final product made it important to establish from the beginning the expectations about the goals of the project, and how the group would reach those goals.

Early on the project museum partners and the DFTV production crew met in St. Paul at the end of April 2008 for a brainstorming and storyline development process. The TV crew talked extensively with the museum partners, most of whom were members of the

NISE Network, about what they had learned so far about the "big ideas" of nanoscience and technology, and what they had learned about how to best convey those ideas. Shortly after the meeting, DFTV staff finalized their proposed scope and sequence of the series. Prior to this meeting, DFTV staff had drafted a tentative scope and sequence, including which topics they wanted to cover, and in what order, and then which museums, and associated university partners, would be a best fit. This plan was discussed in detail with the partners.

Developing a storyline and structure proved to be one of the most significant challenges of the project. In some cases the partners worked very closely together, with equal investment and ownership, to develop storylines for the segments. In some cases, the storylines were as vulnerable to the emerging science as any layperson's understanding. For example, at one site, the group decided to focus on the topic of nanotechnology in fabrics—in particular what are known as "nano pants"—a topic seemingly germane and accessible to a range of audiences. The idea of the segment was to compare the properties of nano pants to how nasturtium leaves repel water. After the research partner spent many hours creating electron micrographs of samples of nano pants fabric and nasturtium leaves, she and the DFTV production staff realized that the science behind the nano pants was different than either they or their partners, including NISE partners, had previously understood. (It appears that the way a nasturtium leaf repels water is a "different mechanism" than how nano pants repel it.) The team, including the research scientist, then had to envision a way to make this very tangible and relevant scientific phenomenon more visual and accessible to the viewer:

> *We had decided early on that we were going to compare the fibers on the traditional nano pants… with the structures of a leaf, because the principle as everyone had been claiming and teaching in nano workshops is that they work the same way. We were working with a scientist at Stanford and gave her the materials…we were due to start shooting on the weekend. The scientist sent us back the photos that she was getting of the leaf and the nano pants. We were trying to find the hairs on the nano pants—we couldn't see them. We wondered 'Where are the little hairs that the manufacturers claim are the reason they work?' So there we were on Friday afternoon [right before shooting was scheduled to begin] wondering how we were going to tell this story…*

In the end that part of the storyline was quickly restructured and the producer felt that the scientist "was our hero" because she was able to point out a discrepancy behind an assumption about the phenomenon and the reality. This would probably not have happened if the scientist and DFTV team had not been working together so closely on the development of the segment. This is a concrete example of how when research scientists are as equally invested in a common and shared purpose—of communicating accurate and current science—as the television production team, the result is a much higher caliber and accurate product.

In a few cases there was confusion and some frustration around who was going to decide which topic would be filmed at a particular museum site. Because of the many complex criteria that a broadcast TV series must meet, both to satisfy its audiences and to complete production on schedule and budget, the choices made may not always match the preferences of the partner institutions. As a result, some disagreements are inevitable. The challenge is to handle those disagreements as diplomatically as possible and ultimately arrive at a win-win solution. Not surprisingly, partners wanted to highlight their relative and unique expertise. For example, some museum partners wanted a greater role in developing the storylines. In one particular case, the museum partner felt that the most important nano research being conducted at their local university would be the best topic to pursue. DFTV chose instead to focus on another topic at that museum, with only a short reference to the local researcher's efforts.

> **Museum partner**: *[It was disappointing] not having more of a say of where we fell in the continuum of this series—that would have played more to our strengths. Because we are limited on resources, I still see it as a better fit to tell a smaller, more focused and specific story. But because of how we were cast in the sequence—for whatever reason we had to be first and we were partnered with this enormous mall of a science center. The contrast was so great. It was disappointing that we were locked in and so the storyline had to change.*

Science Content

Another significant challenge in this particular project was translating nanotechnology language in a way that was scientifically accurate, yet still accessible to a young audience. Due to the respect for the experience of project partners, the DFTV team was able to meet this challenge. DFTV brought to the production years of expertise as science TV producers. This contributed to their ability to target the science appropriately for a younger audience (ages 9 to 12). DFTV also brought what they were learning from project partners about the presentation of nano content (especially through the evaluation of NISE products) to the final product. In addition, they were able to bring the voices and work of the scientists to inform how the science finally was portrayed.

> **Museum partner**: *A lot of the trick is trying to get the content to an accessible level; unless you have someone really integral in the process and who knows the content at a technical level…you can change a phrase to words that kids will recognize, but in changing the wording, you have changed the meaning of the science behind it. Nano seems to fall particularly prey to this kind of thing. So it is a constant tradeoff between making it accessible for your audience and also staying true to the content when it is pretty sophisticated beyond the typical level that you are trying to reach with this age group. DFTV did a fabulous job with the accuracy of the content.*

> **Museum partner**: *They were really packing in [the content]— nanoscience is a tough subject. I think they have a good understanding of their audience and they were really excited about doing some good, tough science. Nano in general is so far removed from anything in human experience; to actually find something that impacts you every day is difficult to do…and they did it.*

One producer said that in hindsight, she believes they may have erred on the side of emphasizing the content, rather than the engagement.

> *The more personal aspects of the kids' stories had to take a back seat. What we've come to realize is that we've over-emphasized the science to the detriment of the more personal details. It's tricky because we're NSF-funded and everyone wants to be responsible to the science, but we're all competing with entertainment and animation. It's not a science show if there isn't any science, but it needs to combine kid-friendly entertainment-driven elements, with the science content.*

In spite of these challenges, when we asked the museum and scientist partners about their general satisfaction with the science content as it was portrayed, overall—particularly given the complexity of the topic, the intended audience, and the length of the episodes—the partners were very satisfied with the final episodes.

Appreciation of and Respect for Mutually Beneficial Relationships

In any kind of partnership, the way that relationships between participants are defined, initiated, and maintained make a significant impact on the success of the project. Throughout our interviews, we heard about the project partners' admiration for the professional leadership of the DFTV crew. This leadership was key to the success of the project, as ultimately, it was understood that this was a DFTV production and the TPT staff had the final say in content and framing. Some partners spoke of how TPT staff lead by "being nice… being kind and trying to make good experiences for everybody." The TPT Director of Science Production credits the management at TPT for giving him the support he needs to develop new projects. Overall, we learned that there was a great deal of respect granted between partners around one another's expertise, and that partner relationships were for the most part handled gracefully and professionally.

Clear and open communication

Perhaps one of the biggest lessons learned from the DFTV Nano collaboration was the importance of clear and open communication from the very beginning of the project. Throughout the project there were a range of topics that needed to be discussed and decided upon, including: the logistics of filming in museums and laboratories; the experiments that would be conducted; the timeline for script and rough cuts; finding the most appropriate museums and scientists; getting approval from the appropriate people (public relations, maintenance and education departments); and agreeing upon who was to conduct all of these tasks. In the end project partners were satisfied with the process and product, but it is clear that some of these topics could have been communicated even more thoroughly and clearly, which would likely have prevented stressful or frustrating moments.

LOGISTICS AND PROCEDURES

Overall, the museum partners we interviewed were very satisfied with the logistical and procedural aspects of the collaboration. They told us that the DFTV crew was very professional, that they were pleasant to work with, and that they followed through on their commitments and responsibilities.

Scientist partners were equally pleased with the communication style of the DFTV crew. In most cases, the partnerships with the research scientists were organized through—and at least somewhat facilitated by—the museum partners. However, there were some cases where DFTV needed to work directly with the scientists to set up experiments and organize the filming process.

> **Scientist partner [based in museum]**: *I have had a really good experience with most television programs produced at our museum, but this one was way above the average in terms of how good it was to work with them and their final product.*

One museum site had concerns about the lack of clarity around who was to serve as the liaison between museum and scientist partners:

> **Museum partner**: *I was surprised by the way [DFTV] handled working with the scientists. I thought I would be more of a liaison. They didn't communicate that—I am very protective of our researchers… I want to be sensitive about how much time they give to science education.*

There was also some confusion on the part of museums and scientist partners about which version of the episode was the "final cut." Some weren't clear, when we talked with them in follow-up calls, whether they would be seeing another draft of their episode, or if the "rough cut" incorporated the final editing process.

We learned that, in the end, these kinds of productions seem to work best when the television producer has the final say and decision-making power, and when all participating partners understand this to be the case. Gerry Wheeler, the Executive Director of the National Science Teachers Association and someone who has long been active in the production of science and technology television programs, describes this well. In an article entitled "Adventures of a Scientist in TV Land", Wheeler noted:

> *I left the premier season of Children's Television Workshop with a new sense of the important of teams, of the value of different kinds of experts, and of the need to get those experts communicating. The scientist has to have a limited veto power on a science show, but he or she should not have the freedom to control the whole*

production. [This show] succeeded in creating interesting and scientifically meaningful experiences for its viewers. This happened by carefully defining the boundary conditions of expertise.[11]

WORK STYLE AND PACING IN MUSEUMS AND TELEVISION PRODUCTION

As one museum partner noted: "…a museum is like an ocean-going vessel and a TV crew is like a fighter plane." Museum partners were asked to participate in this project by conducting a series of tasks, including but not limited to setting up and implementing the "casting call" to recruit youth participants; contacting and communicating with research scientists; finding space for the filming to take place; and creating experiments. They were asked to do this within a period of two months or less. The museums found that what was asked of them and the pace at which they had to work when the film crew arrived —all within a very short timeframe —to be very demanding. Some museums reported that they did not see the final script until as late as the day before the filming crew showed up on their site, which caused them some distress.

> **Museum partner**: *When DFTV got to our museum they were extremely professional and unlike some of the other production crews that have been here… they didn't stay too long… they did what they needed to do and left. So that at least is good, but the lead-up into that, the scheduling and the nailing down times, that is something that I would tell museums that they should be aware of and ready for…*

> **Scientist partner**: *If museums are working with any television production company, nothing happens for a long time and then everything happens at once and it is 100% of your time until it is done, it just rushes to the finish.*

Additionally, some museums have several people or departments who need to be negotiated with for an event such as filming to take place. At times, volunteer coordinators who manage the people on the museum floor, public relations and marketing departments, and maintenance staff need to approve use of a particular space. In cases where the museum partner had not seen the final script, they didn't have time to get everyone at their institution on board and prepared for the process.

Given the differences in timing, pacing, and work styles between museums and TV producers, there was still great trust on the part of the former in the professionalism and reputation of the DFTV crew. The DFTV crew had evolved and refined their strategies for working with museums over the course of two previous series, based on the evaluation findings of Alice Apley, RMC Inc.[12] At the end of the *DFTV Investigating the Nanoworld* project, all participants reported being satisfied with the final product.

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[11] Wheeler, G. (1998). Adventures of a Scientist in TV Land. *American Physical Society – Physics: The Back Page* (Vol. 7, Number 9), Oct. 1998. Retrieved March 5, 2009 from http://www.aps.org/publications/apsnews/199810/backpage.cfm.

[12] Report available at www.informalscience.org.

Building on the Capacity of Experienced Practitioners

One way that this project was very strategic in its original design is that it deliberately built on the capacity of, and invested in already-established and significantly connected practitioners (research scientists, museum educators, NISE partners, TV crew), all with a common mission to provide inquiry-based, firsthand experiences of science. These are all people who care about science and find it enjoyable, so the partnership was not a "forced marriage." Rather it was one that served each institution's mission, drew from each partner's expertise, and truly combined capacities in ways that would not have been possible without cross-institutional collaboration.

In particular, many if not most participants in this DFTV collaboration are members of the NISE Network.[13] As we noted in the introduction to this report, TPT/DFTV are media partners in the Network. As such, the production crew had access to a broad range of resources, people, evaluation results, and networking opportunities to inform the development process for the DFTV *Investigating the Nanoworld* series. This partnership was very strategically designed on the part of TPT, whose crew was able to tap museum partners who have already done a lot of thinking and development around nanoscience and technology education. This allowed them to find partners that were able to quickly get involved with development and production. In addition, the NISE partners had connections to research scientists through the network, and many of these scientists ended up featured or at least included in the productions.

We asked project partners to reflect on how the DFTV team drew on and took advantage of the NISE Network, and to consider how working on this project was the same or different from the development of NISE products. The partners generally agreed that it was strategic on the part of DFTV to draw on NISE expertise:

> **Museum partner**: *Dragonfly was very good at listening to the NISE Net folks and the expertise that they have developed over the course of that collaboration…they took the 'no ego' approach of: 'We don't have to do it for ourselves. What you [NISE members] did was great and we are going to turn it into something else.' They trusted their collaborators enough to start using the existing information that they had, and then build off of that, as opposed to feeling that they need to repeat stuff. A lot of the NISE Net formative evaluation results were very valuable for DragonflyTV because it gave them a more informed starting point. I think they did a very good job of making use of that existing knowledge-base and leveraging other NSF-funded resources.*

According to the Director of Science Production:

[13] The Nanoscale Informal Science Education Network is an NSF-funded project whose purpose is to create a network of informal science education institutions that are interested in developing nanoscience programs and activities for the public. The Network also promotes and facilitates connections between informal institutions and nano research scientists. See: www.nisenet.org.

NISE was critical in raising our awareness to this story and helping us communicate with people in nano education; the existence of the Network contributed enormously to our ability to pull this off, because we could tap into people all across the Network. I guess I would have to say that NISE had in fact paved the way for this project. I would certainly say if we went and [tried to do this]…or the individual museums had decided to do a nano exhibit, but there was no network, it would have been much more difficult to do what we did. NISE raised the general level of awareness and involvement across all of these institutions and so, when we went to try to tell these stories, they already had an interest level and a commitment that we could use.

Several partners felt that conducting evaluation and using those findings was a very important part of what NISE has accomplished in the development of their products. They wondered whether DFTV was conducting formative evaluation on the rough cuts and the content. (They were not aware of the formative evaluation findings gathered by Barbara Flagg.)

Summary of Challenges and Lessons Learned

Institutions sometimes have to adjust their modus operandi in order to make a new enterprise work. The *Investigating the Nanoworld* project wanted to take on the challenge of presenting an emerging science research topic while keeping the integrity of the original DFTV model: i.e., being kid-centered; focusing on real and relevant topics; using everyday materials; presented in a fun and dynamic format; and being inquiry-based. It was a challenge to know how much to compromise while still maintaining partners' core values. Strategic and smart compromise, along with strong relationships, is the keystone of cross-institutional collaboration. Without a clear sense of purpose and compassionate and confident leadership, collaborations can devolve into good intentions without action.

In the case of this project, each partner—the scientists, the museum educators, and TPT—had to give up some proximal benefit for the distal benefit for all. Museums may not have always been able to showcase their highest profile exhibit or program. Researchers may not have been able to highlight their most recent or promising development in their nanoscience experimentation. DFTV producers may not have been able to arrange for the easiest shoot or the most visually captivating experiment in the shortest amount of time possible. But these compromises, when made in good faith, based on a solid personal relationship and borne from a shared purpose, make for a much more powerful and efficient process and product than any one partner could dream of accomplishing or experiencing alone.

VI. Summary

This project was a successful investment and a significant leveraging of National Science Foundation funds. The project experimented with a collaborative model that included institutions with a range of knowledge, expertise, and agendas, and successfully implemented the collaboration to create a product that met the goals of all partners.

We summarize findings under each of our broad research questions:

- How did the partners in this collaboration perceive their commonalities and differences, and to what extent and in what ways did they appreciate the interactions between representatives from the worlds of television production and those of education?

Early in our evaluation, we asked participating members of this project about the differences they perceived between science museums and television in terms of what they felt each could contribute to informal science education. We also asked them to talk about the differences in views about science education overall between these two kinds of institutions. All the partners agreed that each type of organization had something unique to offer that the other could not provide, and they highly valued this opportunity to collaborate and to contribute to each other's work.

- How, if at all, did the partners' attitudes change, regarding the value and potential of this collaboration specifically? How, if at all, did the partners' attitudes change, regarding the value and potential of media/museum collaborations more generally?

We conducted baseline and follow up interviews with most members of the collaboration. In most cases, attitudes about the value of the collaborative did not change dramatically, but only grew more strongly in favor of this project being a worthwhile investment of their time, and of NSF funds. They either suggested or said directly that they would participate in a project like this, with DFTV, again. Even where some collaborators were initially skeptical about being able to make nanoscience accessible, at the end of the project those skeptics were more than convinced that this collaboration made it possible.

- To what extent and in what ways does the three-way collaborative effort of *Investigating the Nanoworld* contribute to innovative presentations of nanoscale science and technology? What, if anything, can be accomplished and produced in a collaborative format that could not be accomplished without it?

There were several ways that the collaborative effort contributed uniquely to innovative presentations of nanoscale science and technology. The DFTV crew brought cutting-edge media and visual animations, and the capacity to produce them, to the project. The

collaborative effort also added to the innovative presentation of nano through the involvement of research scientists who contributed tools, expertise, and imprimatur to the project. And, as we have said throughout this report, the particular assets and strengths of science museums—their expertise in inquiry-based science education, their exhibits and other material resources, and their connections in the community and to universities—all contributed to the accomplishments of this project.

Conclusion

Overall, this collaboration was a very worthwhile and effective project, with a high return on the initial investment. In fact, the total budget was $1.8 million to create six 30-minute programs that will ultimately be seen by an estimated 15 million viewers over the next decade. The work of the partner institutions was complementary, they established good working relationships, and they had a shared purpose with different areas of expertise and capacities to bring to the effort. What is required in such complex partnerships is clear communication about expectations, roles, responsibility, and ownership over decision-making processes. There is a real art to managing the details of such a partnership; overall this project seems to have managed those details in an effective manner.

Appendix A: List of Inverness Interviews

Baseline Interviews Conducted by Inverness Research, May-August, 2008

Inverness Research conducted baseline phone interviews with 18 people at institutions involved with 10 of the 12 *Investigating the NanoWorld* episodes. Most were the museum partners' liaison with DFTV staff, but we also interviewed some PR staff, as well as scientist partners.

In order to build on previous evaluations of TPT/museum collaborations, we developed our interview protocol based largely on one used by Alice Apley of RMC Research, who conducted an evaluation of DFTV: GPS seasons 5 and 6.[14]

Name	Title	Institution	Location
Episode: *Gecko Feet*			
Darrell Porcello	Associate Director of Multimedia Development	Lawrence Hall of Science	Berkeley, CA
Episode: Nano Pants			
Paul Doherty	Director Education Outreach	Exploratorium	San Francisco, CA
Dan Zevin	Senior Project Manager	Exploratorium	San Francisco, CA
Episode: *Stained Glass*			
Olivia Castellini	Exhibit Developer	MOSI	Chicago, IL
Mark Anderson	Graduate Student	Northwestern University	Chicago, IL
Episode: *Nanotextiles*			
Catherine McCarthy	Grant Projects Manager	Sciencenter	Ithaca, NY
Rae Ostman	Director of Education	Sciencenter	Ithaca, NY
Hester Vermaak	Public Relations Manager	Sciencenter	Ithaca, NY
Episode: *Butterfly Wings*			
Brad Herring	Director of Nanoscale Informal Science Education	NC Museum of Life and Science	Durham, NC
Episode: *Where's Nano?*			
Michele Kloda	Exhibits Manager	Morehead Planetarium and Science Center	Chapel Hill, NC
Episode: *Self-assembly*			
Keith Ostfelt	Director of Exhibit Development	Children's Museum of Houston	Houston, TX
Tara Lang	Exhibit Developer and Project Manager for the Matter Factory	Children's Museum of Houston	Houston, TX

[14] Report available at www.informalscience.org.

Name	Title	Institution	Location
Episode: *Water Clean-up*			
Jayatri Das	Exhibit and Program Developer	Franklin Museum	Philadelphia, PA
Vincent Crespi	Director of Education Outreach	Penn State University	Philadelphia, PA
Episode: *Surface Area*			
Adele Binning	Exhibit Developer	Science Museum of Minnesota	St. Paul, MN
Episode: *Bone Regrowth*			
Marilyn Johnson	Director of Research and Development	OMSI	Portland, OR
Anders Liljeholm	Program Developer	OMSI	Portland, OR

Twin Cities Public Television Staff and contractors

Richard Hudson, Executive Producer

Margaret Duden, Research and Outreach Specialist

Kathy Shugrue, Series Producer

Gloria Bremer, Producer

Angie Prindle, Producer

Lisa Regalla, Science Editor

Jo Young, Associate Producer

Lauren Dittmer, Associate Producer

Joan Freese, Manager of Publication, Promotion, and Web