ACROSS THE GREAT DIVIDE

A Thesis

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by

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ABSTRACT

This thesis explores the relationship between art and science through the collaboration of artists and scientists. I worked with four artist/scientist pairs to create ten minute performances and presented them at the Light in Winter Festival, held in January, 2009 in Ithaca, New York. Each pair created their piece over the course of three two hour meetings, the first of which was a cultural probe. The probe was inspired by the work of Bill Gaver, who used playful and creative prompts to better understand communities for whom he designed. Though controversial, cultural probes are a unique way to work with participants to engage in creative thinking.

The probe I created consisted of eight prompts that allowed the pairs to explore the boundaries of art and science and to begin to work together to create something for an audience. The prompts ranged from questions about the participants' careers and work environments, to their impressions of art and science, to their understanding of the roles of artists and scientists. They were asked to draw their workplace, to write their career history in newspaper headlines, to analyze ambiguous images, decide if they were art or science (or both) and write a sentence or title for each image. The final prompt asked the pairs to jointly write a mission statement for their performance. Each pair was interviewed together at the end of the creative process, and for logistical reasons, some pairs were interviewed again informally after the performance. I engaged in an interpretive, contextual description of the process, called "thick description" by Geertz.

Each pair had a unique process. Jim and Lyrae, a physicist and poet respectively, engaged in a dialogue that allowed them to connect ideas and

concepts that did not have an immediate apparent connection. They formalized their process of making connections for the final performance by creating a piece combining excerpts from their published texts. Maren, a dancer, and Itai, a physicist, became interested in the similarities between their processes and presented a piece that explored their processes using video of the wing motions of fruit flies. Trish and James, a paleontologist and a musician, created a narrative about the formation of rock in the Ithaca area and set it to music. Finally, Holly and Spencer, an entomologist and a musician, created an interactive piece in which the audience, armed with plastic slide whistles, took on the role of an invasive species.

Though their projects were quite different, aspects of their process were common to all pairs. Each pair engaged in a process of establishing or reifying boundaries. This boundary work served not only to distinguish art from science, but also to distinguish professionals from non-professionals in each field. While boundaries in the sciences seemed to have more codified structure than those in the arts, boundaries in both fields differed within the subfields.

After the establishment of boundaries, each pair engaged in a process of translation, most often characterized by the use of visualizations or metaphors. Visualizations were often understood by the pairs before they had words to express their meaning, and metaphors were often used to bridge two disciplines. Both visualizations and metaphors were used as tools to help the pairs create a common language for communicating their ideas.

Often this language incorporated boundary objects, those objects that are understood differently by different stakeholders, but used in concert toward a

specific end. The pairs created boundary objects, like visualizations of abstract concepts, they used existing objects, like videos or images the scientists used in their work, and they appropriated objects by changing their meaning for the purpose of the performance.

BIOGRAPHICAL SKETCH

Megan Kara Halpern received her BA in Studio Art in 1997. She began her career in theatre as a set designer and scenic artist, and became a production manager, and eventually a producer. She is the Co-founder of Redshift Productions, a company that connects audiences to science. She works with scientists to create outreach using artistic processes, and she studies the efficacy of outreach programs. She is currently an MS candidate at Cornell University, studying Public Communication of Science and Technology and Artist/Scientist Collaboration, and she will begin her PhD in the fall of 2009. Her research is closely tied to her work with Redshift.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

Prior to coming to Cornell to study science communication, I co-founded and ran a production company that specialized in creating performances inspired by science. During our formative years, we decided to work with scientists to create new performances. This led to a production called *Happy Hour at the Event Horizon*, which premiered in 2005 in New York City, at the Blue Heron Arts Center. To create *Happy Hour* we sent invitations to the science departments in all the Universities in New York City, and we scheduled a different scientist to come in to rehearsal each week to work with a group of improvisational actors over a the course of a year.

At several points during the creation of *Happy Hour*, I found the rehearsals sparked some kind of new insight for the scientists. After one rehearsal, a geneticist who worked with worms said he would never think of his work the same way again. Another scientist discovered that he wanted the public to know that the work he was doing "was art." He was a chemist, working with nano structures and nano robots, and he did not always have an answer for the question of what he was creating would "do." I believe he meant that he wanted people to appreciate his work for the imagination and creativity that went into it, rather than what its practical implications might have been. I was fascinated by these exchanges, and saw them as unique in the world of science. In what other context would these scientists have had the opportunity to think in the way they were encouraged to think during a rehearsal with improvisational actors?

This study is an attempt to generate some understanding of what happens during processes like the creation of *Happy Hour*. I hope to draw out the intricacies of collaboration between artists and scientists and of the relationship between art and science. I began by pairing four artists with four scientists and working with them to create ten minute presentations or performances. For the participants, I believe this was "an experience" in the Deweyan sense of the word. That is, it was demarcated in the general experience as something which "ran its course to fulfillment" (1934, p. 36). Dewey claims that experiences are demarcated by a sense of whole, or a completeness, combined with a sense of aesthetics and with emotion. These were experiences because the pairs were able to consider and express their views on the relationship between art and science, and they were able to share this with an audience. For me, it was also an experience, one in which I was able to explore what collaboration between artists and scientists might mean in the contexts of performance and outreach, but moreover, I was able to begin to formulate a research path to explore the relationship between art and science.

I began where my knowledge as a practitioner left me: I was aware that for artists and scientists to successfully collaborate, I had to find ways to engage them not as 'the artist' and 'the scientist' on a project, but as whole people who were creating something using their unique perspectives and ideas. So my work began with the development and implementation of a highly structured process designed to accomplish the goal of engagement between the participants as well as enrichment my own understanding of their perspectives and their roles in the creation of the performances. From the first meeting, which featured a cultural probe exercise, to the final performance, I taped and documented the interactions of eight people, four artists and four scientists, who

created performances for the Light in Winter Festival, in Ithaca, NY. The artists and scientists were placed into four pairs that met with one another three times prior to the rehearsal and performance of the one hour program, which was free and open to the public.

Each pair's experience was unique, but there were many common themes within their discussions and their performances. In Chapter 3, I will describe the ways in which I engaged the pairs and provide thick description of the experience. In Chapter 4, I will discuss the various ways the pairs used, or did not use, the cultural probe in the creation of their project. The rest of the thesis will focus on the key findings from the study. The findings can be sorted into three broad themes: the ways pairs established boundaries, how they engaged in translational processes, and how they made use of boundary objects. Chapter 5 will explore the boundary work done by each pair, acknowledging both the boundaries they established and the work they did to overcome boundaries they perceived were the norm but with which they did not agree. Chapter 6 will focus on how the pairs worked to communicate or translate across these boundaries. Chapter 7 will show how they went beyond translation, and to begin to establish a common language through boundary objects.

CHAPTER 2

SCIENCE, ART, COLLABORATION, AND PERFORMANCE

Public engagement with science and technology

The idea that that science communicators must engage with the public, rather than merely fill gaps in their knowledge, is a fairly recent development in science communication. Projects inspired by the Public Engagement with Science and Technology (PEST) model (Allum, Sturgis, Tabourazi, & Brunton-Smith, 2008; Bauer, Allum, & Miller, 2007; Rennie & Stocklmayer, 2003; Sturgis & Allum, 2004) have gained popularity in countries like the United Kingdom and Denmark, where citizens are now called upon to discuss the merits of the implementation of new technologies, like genetically modified (GM) foods.

Prior to the engagement model, science and technology communication had attempted to move past the overly simplistic deficit model, in which science communication consisted of scientists and educators disseminating scientific information to the public. The new model, Public Understanding of Science (PUS) incorporated the idea that the public should understand not only the "facts" of science, but also the methods and processes of science. While this was seen as a step in the right direction, the PUS model still implied one way communication, and held the further danger that "understanding" science was often conflated with "appreciating" science. In 2002, officials in the United Kingdom as well as the United States issued statements indicating that, "PUS was an outdated concept that implied a one-way communication from the science community to the public" (Rennie & Stocklmayer, p. 765).

The transition from PUS to PEST has not been an easy one, and there is still much to be learned about how to engage with public. The idea that science should be communicated from the top down is no longer widely accepted in the science communication community, and scholars like Hilgartner (1990) and Lewenstein (1995) have examined the complexities of science communication, first (Hilgartner) as an "upstream" and "downstream" view, in which information travels both ways, and then as a web, or sphere of science communication, in which many actors play a role in the communication process (Lewenstein).

In the United States, the scientific community is lamenting a dwindling pool of scientists with which to work, and as a result, they are redoubling their efforts to reach the public, but the sense that science is "under attack" persists. The difficult task of communicating about environmental issues has been augmented by campaigns that deny the existence of global warming. The unrelenting war between evolutionary theory and religious creationism has seen new efforts to erode the teaching of evolution in public schools (Tierney & Holley, 2008).

Much of the work being done to promote PEST is done through science centers and interactive exhibits, like the Discovery center at the American Museum of Natural History. These experiences are largely designed for small children, and usually museum centered (Bell, Lewenstein, Shouse, & Feder, 2009). There is a growing movement, however, of science based performances both in and out of the museum. According to Shepherd-Barr, the surge of science-themed theatrical performances within the last decade has "made the stage a major forum for the exploration of scientific ideas" (2006, p. 1).

Along with plays like *Copenhagen* (Frayn, 2000), *Arcadia* (Stoppard, 1993), *Wit* (Edson, 1999), and *Experiment with an Air Pump* (Stephenson, 2003), venues such as the Ensemble Studio Theatre's Sloan Project ("EST/Sloan Project,") have emerged as centers for the exploration of science in theatre. These performances are sometimes geared toward children, but often open themselves to broader audiences. They are part not only of the history of science communication, but also the history of work within the intersection of art and science.

How many cultures?

Any discussion of the intersection of art and science is bound to begin with, or at least pay serious attention to C. P. Snow's "two cultures" argument (Ortolano, 2002, 2009; Snow, 1963; Vesna, 2001 to name a few). Though it was not the first appeal for the integration of the sciences and the humanities, Snow's now famous 1959 Rede Lecture has been cited as evidence in many calls for the arts or humanities and the sciences to work more closely together. During the first part of the lecture, Snow bemoaned what he called the "gulf of mutual incomprehension" between art and science (Snow, 1963, p. 4). Though he did discuss the divide between the literary culture and the sciences, the lecture was more strongly focused on education, on morality, and on what he considered pressing global economic problems. Snow's lecture drew heavy criticism, especially from F. R. Leavis, who attacked Snow on the grounds that he was not a true literary figure, that his ideas were naive and simplistic, and his style was atrocious. According to Leavis, the acceptance of Snow by the academy showed a decline in intellectual standards (Collini, 1998). Leavis' response, and that of others like him, was to attempt to rele-

gate Snow's lecture to a marginal place in the academy, but this did not hinder Snow from achieving a more elevated role in the popular imagination. Today, there is scholarly work being done on the two cultures debate; however the debate between these men enjoys more critical and historical discussion than the actual idea of a union between the two cultures Snow was suggesting. Just as Snow's lecture itself was not primarily focused on a real integration of the arts and sciences, neither are the current discussions of Snow's work. The two cultures have been mapped and remapped as different things: science and the humanities; science and the arts; even, in some circles, science and technology or engineering. Often, as was the case in the 2009 New York Academy of Science Symposium on the Two Cultures, the two cultures fall into the categories of science and "everything else."

The current study is not concerned with the political mappings of the many visions of the two cultures that float around the academy; rather, it focuses on the direct interaction of artists and scientists, and of the products of such a collaboration. In this sense, there are three cultures at play: science, art, and the public, or the audience.

The interaction of these cultures has earned a celebrated place in a corner of popular culture. *Seed Magazine*, which bears the tagline "science is culture," has taken up the cause of science and art, on several fronts. First, it cosponsored, along with MOMA, an exhibit called *Design and the Elastic Mind* ("Design and the Elastic Mind," 2008). According to the *New York Times* review of the exhibit, it "makes the case that through the mechanism of design, scientific advances of the last decade have at least opened the way to unexpected visual pleasures" (Ouroussoff, 2008). *Design and the Elastic Mind* was an inves-

tigation into the fluid nature of scale, and our newfound understanding of objects at scales that range from the nano to the cosmos. The exhibit was featured at an art museum, but the artifacts were examples of technological advances, including a chair that constructed itself in the same manner as human bones and a blown glass artifact containing bees that can determine if a woman is pregnant. The curator of the exhibit, Paola Antonelli, wanted to address the newfound love affair between scientists and designers that she says was brought on by the fields of nanotechnology and quantum physics. "Now scientists are seeking designers just like designers are seeking scientists" (Antonelli, 2007). While the distinction between art and design is outside the purview of this paper, the relationship between designers and artists in this case is very close, and often overlapping.

Seed Magazine also featured a cover story in 2007 titled "The Future of Science...is Art?" that predicted art would be the salvation of neuroscience and called for resident artists in science labs (Lehrer). Lehrer believes the future of science depends upon the creativity of artists. In 2004 and 2005, *National Public Radio* did a series on *Morning Edition* called "Where Science Meets Art" that, "explore[d] the unexpected intersections of two seemingly different disciplines" (NPR, 2009). Finally, the expression "the art and science of…" is so prevalent it overwhelms search results of the topics of art and science.

In spite of the attention the art/science movement is currently enjoying, I believe there are visible remnants of Leavis' distain for popular culture which permeate serious scholarly work on the subject. Certainly, the kind of wide-eyed optimism for the future of art and science Lehrer expresses in the *Seed* article are not matched in academia. Though there is much work on visualiz-

ing science, issues of objectivity in visualizations, and the increasing use of aesthetics in science (e.g., Ede, 2002; Kemp, 1990, 2000, 2006b; Lynch & Woolgar, 1988; Lynch, Woolgar, & Myers, 1988), only a handful of important books and journal articles consider the overarching theme of art and science (e.g., Ede, 2005). Still fewer delve into the realm of science and performance (Jackson, 2007; Shepherd-Barr, 2006).

The existing body of work on art and science is far behind the the popular understanding of writers like Johah Lehrer of *Seed* and other popular figures. Certainly my own interest was an outgrowth of my work as a practitioner in merging art and science, not the product of an academic analysis. While I am now committed to studying this field in an academic setting with as much rigor as I apply in my work as a professional (the two are inseparable, in my case), certainly Leavis would not approve of my scholarly work given my background. Still, a systematic, quantitative study of art/science articles and their citation frequency would be most enlightening, and might be a worthy project moving forward.

Science and art in the academy

Still, some work exists in scholarly domains. Ede (2002) divides the intersection of art and science into two categories: artists using science and scientists using art. Artists use science as a way of incorporating new materials into their practice, or they use scientific concepts as themes for their work. Ede correctly maintains that artists have long been, and continue to be, vital to the visualization of scientific information. For example, nanotechnology exists on a scale far too small to be seen by the human eye. New breakthroughs in nanotechnology are often illustrated by artists. Photographs taken by inter-

planetary space probes, as well as images from bubble chambers and particle accelerators are used as album covers. The journal *Leonardo* ("Leonardo, Journal of Arts, Sciences and Technology," n.d.), published by MIT press, was started in 1968 by kinetic sculptor Frank Malina, and has enjoyed some success across a broad range of disciplines. The journal casts a wide net across the arts and sciences, but focuses on ways science and technology can be used by the arts.

Several authors have explored visualization in science through the lens of visual communication and visual literacy (Pauwels, 2005; Trumbo, 1999, 2000, 2005). Trumbo, in particular, is known for her work on visual literacy in the sciences. She offers the following advice:

> The challenge of achieving visual literacy among scientists, communicators, and the public has been acknowledged across disciplines as diverse as the arts, computer science, cognitive psychology, communication, engineering, and the life and physical sciences. It is important to recognize that while the tools of data visualization and visual representation are evolving quickly, the potential for visual representation of science information to carry meaning or to be understood in an accurate way by an audience is an important issue for researchers to examine. Communication researchers can contribute to the effectiveness of such efforts by turning a critical eye toward the function, purpose, and effects of visual representations in the sciences. (2005, p. 280)

Kemp (1990, 2000, 2006b) has been writing a science and art column for *Nature* for some time, and has compiled several books based on his work for *Na-*

ture. While his work appears in the general rather than peer reviewed side of *Nature*, Kemp is a well regarded scholar on the subject. He discusses the visualization of nature in both art and science from an historical perspective, exploring phenomena like perspective drawing. He argues, for example, that "there is no illusionistic trick in the pages of *Nature* or *The New Scientist* that does not have its counterpart in Renaissance art and science" (2006b, p. 323). Kemp has written extensively, as well as produced traveling exhibits about Leonardo Da Vinci (Kemp, 1977, 2004, 2006a; Kemp & Wallace, 2000). Much of the content of his work on Da Vinci has to do with visualization, including perspective and technical drawing.

Beyond Kemp, many scholars have examined aspects of visualization and the use of art in science. Daston and Galison (1992) examine changes in the meaning of objectivity that resulted from the use of new methods of artistic reproduction, like the camera obscura, and eventually, the camera. They found that these tools allowed new forms objectivity, thus changing the nature of objectivity. Once defined by artists, this new, mechanical, objectivity, became a moral issue.

Finally, Latour (1998) suggests that the history of science has much to learn from the history of art due to the inherently constructivist character of art.

> It is possible to take much greater pleasure in learning the laws of the thermodynamics after having read the social historians on the first or second law, but this reading, precisely, takes on some aesthetic character. The same mediators that should have been black-boxed to produce scientific certainty, now that they are developed by the historian, generate a type of pleasure that we rightly associate with the arts. Even if I exaggerate the differences, it re-

> mains fair to say that Beauty is more easily seen as a construction than is Truth. (p. 423)

Art, science, and imagination

Daston (2005) describes a clear split between science and art after the Enlightenment. During the Enlightenment, both art and science were imaginative, but tied to reason. Daston describes the rise of the concept of objectivity as the downfall of imagination in science. As science came to be defined by its ability to be reproduced, art became more and more defined by its radical subjectivity.

It seems, then, what Lehrer might be hoping for in his vision of the shining future of science and art is nothing more than a return to the use of imagination in science. The question then, would be whether this return to Enlightenment ideals, including the mingling of imagination with reason in both art and science, would lead to more reasoned art. If so, what might the effect of Lehrer's vision be on artists?

Holton (1978, 1996) describes the "art of the imagination" as a key ingredient in scientific progress, and in Popper's famous discussion of the deductive process of science, he talks briefly about the beginning of the scientific process; "there is no such thing as a logical method of having new ideas, or a logical reconstruction of this process. My view may be expressed by saying that every discovery contains 'an irrational element', or 'a creative intuition', in Bergson's sense" (1959, p. 32). Clearly, there is agreement that, in spite of the rise of objectivity, imagination plays a significant role in science. Further, imagination is something that is shared between art and science. But does this help to understand the possible relationship between art and science?

Only up to a point, beyond which I find my own research interests. For example, I am interested, like Lehrer, in the future of art and science. How can we better understand the intersection of the two, and in what new ways can they be combined? According to Ede, Kemp, and many others, it seems one must always serve the other. I hope to challenge this assumption by creating a collaborative environment for artists and scientists to work together.

Art, science, and public performance

This broad concept cannot be fully explored in a single Master's thesis, so I began to narrow the focus by producing a specific event, the Light in Winter Festival, and a particular interaction between artists and scientists to create public performances.

Public presentations incorporating art and science often take the form of art or performance about science. The same 'art or science' tension often creeps into any conversation about these events: some see them as opportunities to educate the public using performance, others see them as art or entertainment with a scientific muse.

Copenhagen (Frayn, 2000), a play about the final meeting between Neils Bohr and Werner Heisenberg has been discussed often for its ability to be both a work of art, and a way of expressing complex scientific concepts to lay audiences. Still others see the play as a way of helping the public understand the implications of the uncertainty principle and of the stakes of scientific discovery during a time of war (Shepherd-Barr, 2006).

Modern science theatre is rooted in the living newspapers produced by the WPA during the New Deal. Hallie Flannagan, who ran the WPA theatre pro-

gram, employed out of work, depression era, actors by creating performances designed to provoke thought about current issues in science and medicine, like syphilis (Jackson, 2007; Shepherd-Barr, 2006). According to Jackson, science theatre has a "tendency to resort to nonnaturalistic forms, to dramatic poetry, to language and staging techniques that can capture the ambiguities and the complexities more effectively… [which] can perhaps transcend the messenger-receiver paradigm" (Jackson, 2007, p. 124).

Not all science plays are based in nonnatural expressionistic forms. Carl Djerassi, famous chemist-turned-playwright, often uses quite naturalistic stories in what he calls "science-in-fiction." Djerassi says he hopes to smuggle science into the consciousness of a scientifically illiterate public through interesting realistic dramas (Djerassi, 2007; Jackson, 2007).

Other than Djerassi's reflections on his own work, we have little beyond historical accounts of science theatre. These histories are quite useful, up to a point, but there is much work to be done before we can begin to understand what role these performances play in what Lewenstein (1995) refers to as the web, or sphere of science communication. With this study, I hope to shed some light on where these various literatures (science and art, science and imagination, and science and performance) meet, and open the doors for new research that will help illuminate all three areas.

CHAPTER 3

"ACROSS THE GREAT DIVIDE"

I began this project with broad research questions: First, what are the processes and effects of artist/scientist collaborations and what are the implications of these processes and effects? My aim was to understand a creative process between an artist and a scientist; moreover, to understand what effect their collaboration would have on their own work as well as on the outcome of the projects themselves. A larger question sits in the background: what can I learn about the nature of the relationship between art and science by looking through the lens of creative collaborations. It is clear that there are commonalities between art and science, but what makes them similar? And what causes the perception that they are so different? The nature of this relationship merits exploration both practically and theoretically. At this stage in my research, I will attempt to answer this larger question about art and science through the lens of the questions about artist/scientist collaboration.

Having observed quite a number of these kinds of attempted collaborations in the past, I knew that when unguided, they fall into a pattern in which the scientists present their work and then the artists attempt to make something from that presentation, asking questions for clarification. My work on *Happy Hour at the Event Horizon* taught me that this doesn't always yield the best outcome (though occasionally the results are profound) and that in order for the scientists and artists to learn from the experience, a more integrated collaboration is necessary. I also learned that these integrated collaborations often yielded work that the artists and scientists involved found more satisfactory. This study is an attempt to formalize what I'd learned as a practitioner, and to fur-

ther explore the concepts in order to understand their broader impact on those involved.

I guided four artist/scientist pairs through an experience that began with a cultural probe and culminated in a performance for the Light in Winter Festival in January 2009. Each pair created a 10 minute performance, and all four were presented at an event titled “Across the Great Divide.” This chapter will discuss each case individually, as well as the design of the process and my role as a participant observer.

To maximize the likelihood of recruiting and retaining artists and scientists who would be willing and able to participate, I limited the study to three meetings per pair. I advertised locally and recruited a mixture of academic and professional artists and scientists. This was not easy; I received a number of responses from people who could not commit to the meetings, and several responses from people who, once they understood what the project was, didn’t feel it was a good match for them. Ultimately, most of the people who agreed to work with me already had an interest in either the Light in Winter Festival or had participated before. They were interested in the intersection of art and science, and thought it was valuable. This was not a large group of people, so it certainly affects the results of the exercise very deeply. I paid the participants a small honorarium for their time. Once I had 8 participants signed up, I chose the pairs primarily by accommodating their schedules, which made the assignments fairly arbitrary; however, I am certain that my impressions of participants guided me somewhat in my choices. Though I did not intentionally plan it, each pair consisted of one male and one female.

The design

Each of the three meetings had a specific goal for the pairs. By the end of the first meeting, they were to have a mission statement for the project they would create; by the end of the second meeting, they were to have a basic script of their performance, as well as a plan for any "homework" they might have prior to the third meeting, which was a rehearsal of their performance, followed by an interview about the experience so far.

Meeting 1: The cultural probe

The first meeting with each pair was a cultural probe, inspired by the work of Bill Gaver (Gaver, Boucher, Pennington, & Walker, 2004; B. Gaver, A. Dunne, & E. Pacenti, 1999). Boehner et al. define the probes as "designed objects, physical packets containing open-ended, provocative and oblique tasks to support early participant engagement with the design process" (p. 1077). Gaver's most widely documented work with cultural probes was part of his research for The EU Presence Project, in which Gaver et al. worked in three European cities that used design to increase the presence of the elderly in their community. They provided a probe for a group of elderly people to better understand their wants and needs. By administering the probe, they were able to create an experience with a playful spirit; they were able to learn about individuals in the community they were trying to serve; and they had opportunities for rich dialogue between themselves and the seniors. While the information gathered from the probe inspired the designers, it was also meant to provide direct benefits to users. "Trying to establish a role as provocateurs, we shaped the probes as interventions that would affect the elders while eliciting informative responses from them" (B. Gaver, T. Dunne, & E. Pacenti, 1999, p.

25). As Sengers et al. put it, “If a person is asked to report on the role that buses play in their lives, to take photographs and notes and draw pictures of buses, then when they cease that activity they will themselves see buses in a different light. We acknowledge, embrace, and design for that effect” (2004, p. 20).

Since Gaver’s work with the elderly communities, there have been many permutations of cultural probes, mainly in the field of human computer interaction. Gaver’s probes were left with participants to complete on their own and return to Gaver and his team. Likewise, the implementation of most probes is not directly observed, but rather the evidence that is returned is used to inspire the design process. There is much debate concerning the proper uses and designs of cultural probes. Gaver, and others, explicitly say that probes should not be used as a method for collecting data, but rather as a way to interact with and inspire/be inspired by users. Some concerns over the misuse of these probes include their use as a sort of “discount ethnography” in which researchers substitute time spent observing people with time spent analyzing their probes.

Still deeper concerns regarding the probes have to do with the probes employed in conflict with methodology. In these cases, probes are used within the context of a more traditional set of methodologies, “producing data instead of producing responses, closing instead of opening the design space” (Boehner, et al., 2007, p. 1084). While Boehner et al. explicitly state there are unlimited possibilities and interpretations of probes, they advocate clear, well-reasoned ideas of why probes are implemented, and an understanding that probes are meant to be interpreted rather than quantified.

The probe I designed differed from Gaver's in several ways. First, rather than using the results of the probe to inspire my own work as a designer (though

Figure 1: A cultural probe assembled prior to the first meeting.
Figure 2: Jim and Lyrae in the process of completing the cultural probe

they did affect the way I designed the experience), I used the probe to spark collaboration and design ideas among the users themselves. Additionally, because the pairs had to complete the probe together, I decided to administer the entire probe in a single meeting, and I observed the entire meeting. Gaver's probes were dispensed to participants to complete on their own and then either collected or mailed back to the researchers involved. For Gaver, a cultural probe was often a way to get to know a culture from afar, which is one reason it is important to him that probes should be used to inspire design rather than to collect data. Gaver, as well as Boehner et al. warn of the danger of administering a cultural probe in place of observation or other data. Be-

cause I was present for the probe, I was able to perform direct observation of the pairs interaction. If I had attempted to draw conclusions from the products of the probe without context, I would not have learned much.

The probe was also designed to encourage creativity as well as provoke discussion between the pairs as they developed their performances. Specifically, I had four goals for the probe 1) to help the pairs develop a rapport and working relationship, 2) to inspire creativity and meaningful conversation as they thought about what they wanted to do for their performance, 3) to serve as a kind of interview that each pair would answer collaboratively rather than individually, and 4) to serve as a tool for planning and executing the rest of the experience.

The cultural probe consisted of eight activity prompts listed in Table 1. Each prompt was contained inside its own envelope, and markers and paper were left on the table (Figures 1 and 2). I included prompts that suggested discussion, as well as prompts that suggested activities like drawing and writing. Most topics focused on either each individual's work, or on the broader theme of art and science. The final prompt asked them to write a mission statement for the piece they would like to create. After the meeting, I scanned the notes the pairs took, including the text of their mission statements, and uploaded them to a private site so that each pair could see their own work. Much of my analysis ended up coming from this initial meeting, as this was the crucible of the collaboration, and provided rich information about the participants' beliefs regarding art and science, as well as their approaches to collaboration and brainstorming.

Table 1: Prompts from the Cultural Probe

1. *"I begin each day of my life with a ritual: I wake up at 5:30 AM, put on my workout clothes, my legwarmers, my sweatshirts, and my hat. I walk outside my Manhattan home, hail a taxi, and tell the driver to take me to the pumping iron gym at 91st street and First Avenue, where I work out for two hours. The ritual is not the stretching and weight training I put my body through each morning at the gym; the ritual is the cab. the moment I tell the driver where to go, I have completed the ritual." -Twyla Tharp*

   What rituals begin your work? Take us through them. Write them down or draw them. At what moment are your rituals complete? At what moment do you begin your work?

2. *Find 5 things you have in common.*

3. *Draw an Artist or Performer. What words or phrases do you use to describe artists and performers? Draw a scientist. What words or phrases do you use to describe scientists?*

4. *Respond in any way you see fit to each of the following quotes (see Appendix 1 for a list of quotes).*

5. *(See Appendix 2 for all images accompanying this prompt) Is this art or science? What does it mean? If you had to write one sentence together that would capture the meaning of this image, what would it be?*

6. *Write the history of your career in Newspaper Headlines. Tell each other your histories. How are they different? How are they the same? Would your stories be in the same papers?*

7. *Draw where you work. Draw your favorite thing about your work. Draw your least favorite thing about your work*

8. *Write a mission statement for the piece you will create. What will it do? What do you want the audience to think about?*

Meeting 2

After reviewing and analyzing the first meetings, I decided to provide each pair with transcripts from the final prompt in the cultural probe, in which the pairs developed a mission statement. I wanted them to have access to their conversation about the mission of the piece, rather than just the statement itself. The aim of this meeting was for the pairs to work with the mission statements to

generate ideas for what they wanted to do for the performance. The structure was quite loose, and the pairs were tasked with deciding what they wanted to do and how it was to be accomplished. To engender the same kind of creative and playful atmosphere established during the cultural probe, I also provided additional creative tools, like drums, balloons, construction paper, and markers, and asked them to bring what they considered their creative tools, or tools they thought would be useful to create the performance.

Meeting 3

By the third meeting, the majority of the creative work had been accomplished, and the task for most of the pairs was to refine and rehearse their performances. After the rehearsal, I interviewed each pair together about their experience and what they hoped or believed the audience would gain from their piece. For logistical reasons, some, but not all, participants were also questioned again individually after the performance.

Participatory Observation

I have a background in creating science performances by working with artists and scientists, and I had an opportunity to create a performance for the Light in Winter Festival, so I felt it would be beneficial to use this performance to create several cases in which to study the process of artist/scientist collaboration. These four case studies would allow me to compare the collaborative process with like projects.

There are additional comparisons that will enter this study due to my background as a practitioner. Specifically, I will discuss these cases in the context of my previous work on *Happy Hour at the Event Horizon*. While these re-

hearsals resulted in a final performance, the process and what value the scientists and artists believed it held for them interested me much more than the production itself. Since my participation in that process is what led me to academic research, I felt it would be artificial not to consider this part of the context of the current study.

Similarly, I thought it would be artificial to try to remove myself from the process: my participation would enrich the experience for the artist and scientists participants as well as my understanding of the study. Some maintain that all social research is participatory because it is impossible to divorce oneself from any social world (Atkinson & Hammersley, 2005; Hammersley & Atkinson, 2007). In this case, I was engaged in participant observation that, as Atkinson and Hammersley say, spanned the gamut of "complete observer, observer as participant, participant as observer, and complete participant" (Atkinson & Hammersley, 2005, p. 248). Though participant observation (in all forms) is open to much criticism, it is an invaluable and unique way of generating rich descriptions and interpretations of meaning about particular social phenomena.

My work at times exemplified each of the four categories listed above. I created and designed the experience, so I was not observing artists and scientists as they would naturally behave without my intervention; however, I did not actively participate in the first meeting[1], but instead used the prompts I designed as my participation. I did not answer questions about the prompts, which occasionally frustrated participants, but there was no correct answer or way to proceed, and I wanted them to interpret each activity or question them-

[1] In one instance, I did briefly intervene; see the description of Lyrae and Jim's first meeting

selves, and to work together to answer their questions. After administering the prompts and reviewing the meetings, it became clear to me that the mission statements the pairs generated should become their roadmap for the next meeting. Attempting to create another structured experience would likely distract them from the work they needed to do to create the performances. I decided that rather than structure another experience, I would provide the pairs with an open structure, and take on a more participatory role. While I did not attempt to generate ideas for the performance itself, I offered problem solving ideas and guidance regarding what was or was not feasible within the scope of the production. During this meeting my role transitioned from observer to co-collaborator, and in some cases, director. This new role arose organically, and the way I participated varied with each group according to their needs and my ability to help them prepare for the performance. In most cases my role as a director was clear by the third meeting, and artists from two of the pairs indicated that they thought of me as their director.

Data analysis and "thick description"

> "Believing, with Max Weber, that man is an animal suspended in webs of significance he himself has spun, I take our culture to be those webs, and the analysis of it to be therefore not an experimental science in search of law but an interpretive one in search of meaning" (Geertz, 2000, p. 5).

The rest of this chapter will be spent providing rich, detailed descriptions of each pair's process and performance. Through this "thick description" (Geertz, 2000) I will begin to explore my observation and interpretation of the collaborative process. This description is meant to explain the events that oc-

curred during the project as well as their context. Geertz borrows the term "thick descirption" from philosopher Ryle (2000), who gives the example of an observation of a wink. In different contexts, the wink may have completely different meanings, and it is up to the observer of the wink to interpret the meaning. Similarly, I am part of the context of the collaboration between these pairs, and as such, I am able to interpret their actions.

During the project, my role changed according to the circumstances and needs of the pairs. Because of this shifting role, some decisions were made exclusively by the pairs, while I participated in others. I attempt to indicate my own participation with the use of first person rather than third person language. For example, when the pairs came to a conclusion or made a decision, I would refer to the action as something "they" did, but when I was involved, I refer to what "we" did. In most cases, I don't feel the distinction greatly altered the outcome of the process, but in those few instances I am aware of the ramifications of my intervention, I discuss them at length.

The pairs

Jim and Lyrae

Jim, a professor and a theoretical physicist was paired with Lyrae, a professor and poet. During their first meeting, they discussed themes in their work rather than completing the prompts they found in the cultural probe. This loose interpretation of 'the rules' allowed them to focus on ideas that excited them, and to disagree with what they perceived as the aim of the exercises. For example, when given the prompt to draw a scientist or an artist, Lyrae rejected the idea that the two were separate at all. "Don't divide me from my fel-

low person!" she exclaimed. Then, instead of drawing, they embarked on a discussion of the similarities between artists and scientists, which led to a conversation about beauty in the sciences and the arts, which, in turn, led to a discussion of superconductors, cooper pairs, and sixties dancing. The following conversation took place toward the end of the meeting, and provides a sense of how they were interacting with one another.

> Jim: Entropy encapsulates how much you don't know about the thing you're trying to deal with. And I think that's the most powerful aspect of it.
>
> Lyrae: I think that sounds like an open interval to me. It encapsulates how much you don't know, and how much you don't know is always evident to me in terms of...
>
> J: It encapsulates what you don't know about something
>
> L: Oh, okay.
>
> J: so its the entropy of the air inside this glass, you know some things about it, we know sort of how many atoms are in there, you know sort of their average energy, but where each molecule is, we don't have a clue.
>
> L: Yeah, that's what I mean.
>
> J: And quantifying that is an incredibly useful tool, you can describe almost everything about the air in that gas just from the fact that you don't know where the atoms are. That is our way of explaining the laws of gas dynamics and frankly about everything else, it's what you don't know that tells you the behavior...
>
> L: That just made me think of tatting lace, if you want to know how my crazy mind works, tatting lace, the process of making lace.

J: Yes?

L: Because it's always in anything that you study, including poetry, including anything—which is why I am obsessed with the open intervals—it's the space that makes the pattern, it's always...exactly what you said: the thing that you don't know, makes everything.

J: so tatting lace, it's the holes between the...

L: Yes!

When they began to discuss their mission statement, Lyrae expressed her desire to create opportunities for audience members to have a conversation with someone they had never met before. She indicated that this was important to her not just in this endeavor, but in all endeavors, so she and Jim spoke for quite some time about how this might be accomplished. They attempted to attach a scientific concept to the idea of moving the audience, but did not fully formulate a connection. Their most thorough attempt was with the concept of entropy, which was of particular interest to Jim. This strong desire to spur audience interaction drove the discussion of their mission statement, so much so that it seemed any scientific ideas they might want to engage with were becoming footnotes. I intervened to ask Jim what was of interest to him, in hopes that a scientific concept would help refocus them or provide a more clear direction for the participatory experience they were trying to create. Jim was fairly opened to examining different aspects of his work, but returned to the idea of entropy.

When they returned for their second meeting, they did not immediately focus on audience participation. They came to the meeting remembering that they found their exchange of ideas from the previous meeting quite enjoyable.

They focused on this idea for the majority of the meeting. Jim described several games in which disparate things are matched together. The first was a children's book that was cut into three sections, each with different heads, torsos, and legs, respectively. The child could choose different parts from each section to make up a whole person. This way, there are a relatively large number of combinations for creating a person. The rest of the games were a variation on a theme of joint storytelling. In one, someone would begin a sentence and stop at a certain point, at which time the next person had to finish that thought and begin another, and so on. What each of these games had in common was the fact that they allowed for multiple combinations of seemingly random, yet ultimately connected things or ideas that, when combined, make a whole. They were also an analogy to the back and forth of ideas that Lyrae and Jim had enjoyed so much during their first meeting.

These games became the basis for an exercise they devised in which they would take turns choosing a single line or sentence from one of their own published works. These lines would be connected in some way that made sense to them but was not necessarily apparent to anyone else. They used one computer and switched back and forth between documents, so they could watch one another's process while they worked. They had vastly different methods of deciding on the next line. Lyrae made decisions quickly, she chose the line first and then explained the connection to the previous line after. It was not, however, as though she chose the line instinctually, while Jim did so analytically. She was very clear about her reasons. Later, during the exit interview she explained her ability to clearly choose lines more quickly than she could explain her choices. She told me that she sometimes has a more difficult time speaking about her work than she does writing about it, and that

she felt she was not able to fully express what she was thinking. Jim reasoned out each of his lines, needing to find a reason for their connection before choosing them. Choosing Jim's lines became a joint effort, because Lyrae would see a line as he was moving through his work and would become very excited about it. After completing several lines together, they determined that they had created something interesting, and that it would form the basis for their performance. The text is reproduced in Table 2, with Jim's lines appearing in beige and Lyrae's in pale blue.

Table 2: "conversation" created by Jim and Lyrae

Nature is very complicated
I cannot tell a dipper from Orion
What happens, then, when atoms change their mind?
Love's gorgeous force:— a tight fat cloud of blue
Relieving cholesteric frustration: the blue phase in a curved space
Winking delay: the crushing need for form
Crystals, when formed or deformed, relax by developing walls
An opal pressed to her left palm. See her? A sliver in a polarized light?

They decided to return at the next meeting to asses whether they needed additional lines. At this point, I introduced the subject of audience involvement again, because it had been so central to Lyrae's reasons for engaging the project. I wanted to ensure that they were both satisfied with the outcome. Another lengthy discussion did not result in any concrete ideas of how the audience participation could relate to the piece they had created. They both wanted to find some way to give the audience an opportunity to experience what they had experienced in creating their conversation. As they tried to plan this, I became more involved in the conversation. I was concerned that some

of their ideas were asking too much of an audience in too little time. Whether to intervene was a difficult decision for me, both in the moment, and upon later reflection. I did not want to hamper their creativity or place my own value judgements on their piece. However, I thought they would ultimately be dissatisfied with a performance that did not come off well because of a participatory element, so I became very involved in the discussion.

Because their performance was not predicated on a specific scientific concept or an art form, but rather on a collection of loose but interesting connections, they had a very difficult time trying to create an activity that was self contained and clear for the audience. We left the meeting in agreement that we would incorporate audience participation in some form of an exchange, similar to their own, between audience members who did not know each other. They did agree that the conversation they had created felt somehow complete, but the conversation alone would not engage the audience, since they would have no context for it. Jim brought up the idea of adding visual images to their piece, and volunteered to provide a powerpoint file with appropriate images for the next meeting.

During the third meeting, we spent a good deal of time going over the images and refining them. Jim suggested they read the piece twice, once without and then once with the visual images. They also decided to illustrate their process by reading it a third time while discussing their reasons for choosing each line. They tried this once in the meeting and both felt that it was the missing piece of their performance. They also agreed they would like to meet one more time prior to the technical rehearsal so they could rehearse their piece. This time, I agreed to refine the visualizations to make them appear less like a traditional

powerpoint presentation and more like a projection component of a performance.

I brought up audience participation one last time during the third meeting, feeling that I had discouraged them in the previous meeting. But, once again, we failed to create a clear activity. The idea that the audience would mimic their own experience remained, but none of us could find an elegant way to make this happen during a ten minute performance. We agreed to keep this idea in our minds for the next meeting.

That meeting was held in the performance space, simply because I found out it was available. They rehearsed several times, and realized that the three iterations of their piece took the entire ten minutes. I felt I had returned to the idea of audience participation enough so did not bring it up again, and there was no further conversation about it.

Maren and Itai

Maren is a dancer as well as a dance instructor and massage therapist living in Ithaca. Like many artists, she must hold several flexible jobs to make a living and pay for continued dance class. Itai is an experimental physicist from the physics department at Cornell University.

Maren and Itai were much more committed than Jim and Lyrae to completing the prompts in the cultural probe, and worked through each task carefully and thoughtfully. They occasionally asked for guidance on prompts, but I gave none. Itai frequently turned to humor to move the conversation forward. Maren and Itai discovered several themes that were important to them during the cultural probe. Their conversations often turned to ritual, language, scale,

and aesthetics. These themes came directly from the probe itself; however, because each pair's process was so different, it is important to understand what about the probe was particularly resonant for them.

Itai and Maren discussed the nature of beauty quite a bit. Itai had a great interest in the connection between science and beauty. "Maybe there is a very strong link between, you know, nature, and the things that scientists are trying to probe, and are attracted to explaining," he said, "and the things that we see as beautiful." This echos something Jim said about seeking beauty in science during his first meeting: "I'm not interested in an answer that isn't beautiful, I want to understand it in a way that is fun and interesting." For Maren and Itai, prompt 5, in which they looked at images like the one in Figure 3, led Maren to ask what makes something beautiful, and Itai to discuss his interest in whether there was an evolutionary component to our understanding of beauty.

Maren and Itai both referred to their disciplines as "languages." When asked to draw artists and scientists, and write words that describe them, Itai referred to scientists as linguists. Maren compared this to the "language of dance." They returned to the theme of language in prompt four, when they encountered the Heisenberg quote, "Both science and art form in the course of centuries a human language by which we can speak about the more remote parts of reality…" While they did not dwell on the language aspect of the quotation during the prompt, they did revisit it during their formation of a mission statement.

The subject of scale first came up during a discussion one of the images in prompt five. The image (see Figure 3) happened to have a scale notation on the left hand side. The note simply indicated a length measurement for 100

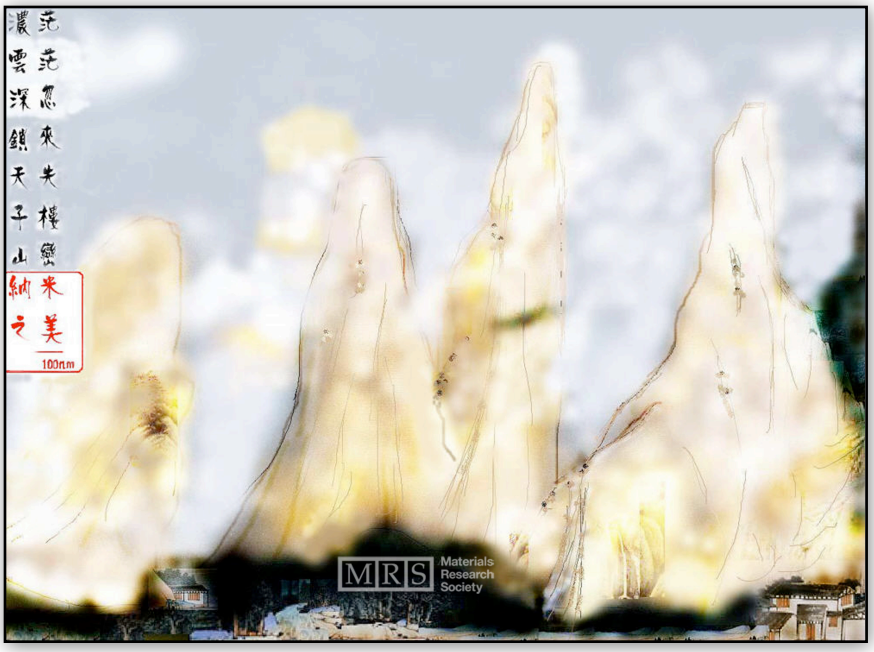

Figure 3: an Image used for Prompt 5 in the Cultural Probe. This was the Second Place Winner in the 2008 "Science as Art" Competition at the Materials Research Society (MRS) Spring Meeting in San Francisco. The image was created by adding color to a ZnO nano-needle SEM image (Yang, 2008).

nanometers. Maren and Itai spent a great deal of time trying to puzzle out what the image was (they were not given any information other than what was on the image itself), and what role scale played in the creation and meaning of the image. Scale came in to play again at during their discussion of the mission statement. Itai had an interest in working with some films of fruit flies. These fast movies were shot at 3000 frames per second, so the flies appeared large and they seemed to move slowly. Maren, who said she was used to swatting at fruit flies, was very interested in the different scales at which she now understood fruit flies.

When they formed their mission statement, they drew upon all of these themes. Like Jim and Lyrae, they were very interested in incorporating audience participation. Rather than wishing for the audience to interact with one

another, Maren expressed a desire to raise questions that the audience could consider, and Itai expressed interest in getting them to move or dance. Once again, the two had a lengthy conversation about what they wanted to do and how to go about it, but did not come to any conclusions.

In their second meeting, Maren and Itai continued to discuss the similarities between the process of art and the process of science. As they continued to work with the fruit fly videos, it be came clear that their goal was not to teach the audience about the flies, but rather to use the flies to illustrate the similarities between their disciplines. They broke the process of science into three phases: data collection, analysis, and presentation, and they compared this to the process of dance. Maren describe her process in the same terms, "And the way I collect data, by walking from the parking lot, I notice the way the leaf is hanging on the tree. Everything is data, and maybe I can improve something…" She also said that she would never use the word data, so the three of us began to discuss words that would apply to both of their processes. We arrived at three words that would encompass both: observe, interpret, and share. See Figure 4 for the way they envision the three parts of their process working together.

They used this image to create the crux of their piece. As Itai was explaining the process, he physically began to walk in a circle, and Maren began following him. They each explained their own processes in terms of this image. As their performance took shape, they incorporated parts of the conversations they'd had about Itai's work with fruit flies, and about Maren's work as a choreographer. For the performance, Itai described his work, and then his process, walking in a circle as he described his observations, interpretations, and

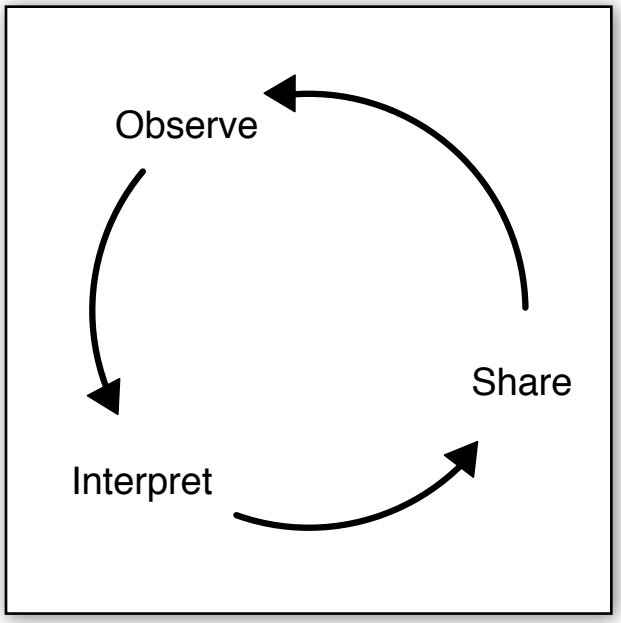

Figure 4: Maren and Itai's visual model for their processes

sharing, and Maren followed him, described her process in using the same terms, and then showed her process with two very different interpretations of the same film of fruit flies. Her choreography for each interpretation was set to different music, and incorporated ideas, like scale, from their conversation during the first meeting.

Trish and James

Trish is the Evolution and Global Change Projects Manager at the Museum of the Earth. She has a background in Paleontology. James is a visual artist and musician, and an Ithaca resident. Their meetings were quite short, and as a result, we added an additional meeting for the rehearsal/interview. Like Maren and Itai, they followed the prompts closely. During their first meeting, Trish and James locked quickly on to a visual image, an hourglass, that helped them express their understanding of the relationship between art and science,

and helped them develop their mission statement. They played with variations on what each end of the hourglass meant, but in each variation, art and science met in the middle. See Figure 5 for their image.

When they reached the final prompt and began to create their mission statement, they did not spend a great deal of time on the questions, “What will it do?” and “What do you want the audience to think about?” Rather, they began to talk about what they would like to do, or what they could do. Subsequently, they were the only group not to consider audience participation. They were

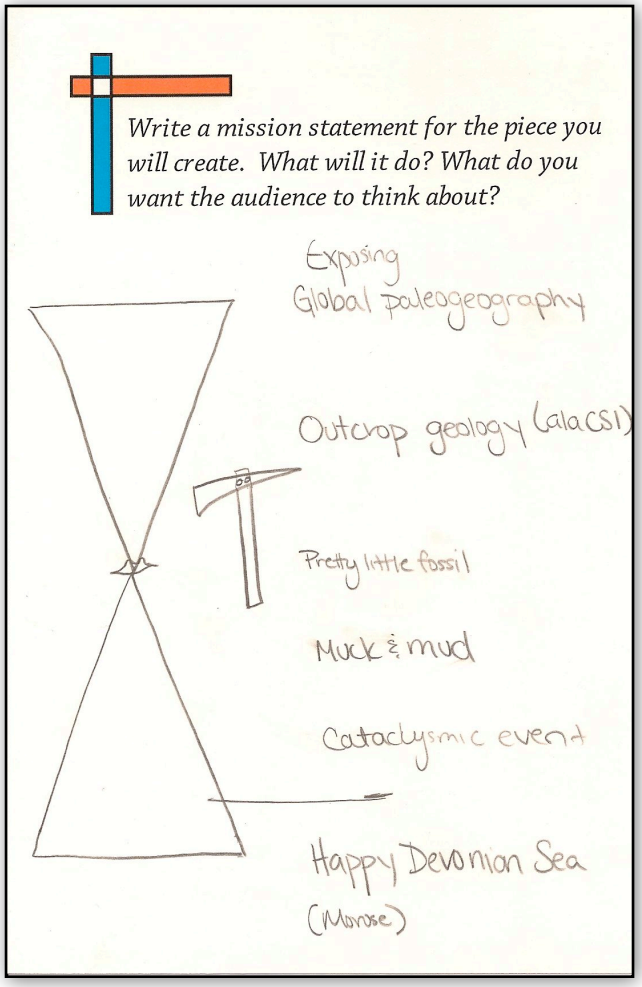

Figure 5: Trish and James’ visual model for their performance.

driven by the excitement of creating something, rather than a desire to communicate a particular concept or evoke anything specific in their audience. This is not to say that they were disinterested in the audience, they gave no indication of that. It appeared more that they were enthusiastic about the prospect of making something, rather than about public understanding, whereas the first two pairs put more of their efforts into thinking about what they wanted the audience to experience or to think about.

Trish and James decided they wanted to create something together, and to do that, they should find a fossil together. During their conversation about their work earlier, both of them had described their processes. James mentioned his interest in making music by looping sounds that came from something other than a musical instrument, and Trish explained what it was like to go into the field and look for fossils. When they were planning their project James suggested he audio tape Trish's footsteps and her hammering on some of the rock. A field trip was planned for the two of them to go fossil hunting together near one of the gorges; however, none of us took into consideration the fact that we were in upstate New York, it was late November, and their next meeting was to be December 20. The trip was scheduled for December 19, and plans were made to record Trish's footsteps and digging.

On Dec. 19, there was a blizzard. Most public schools were closed, and there was no chance of getting anywhere near rock, let alone taping the crunch of hiking boots on the ground. They agreed they wanted to go ahead with the regular meeting the next day. Due to the last minute changes, that meeting was somewhat improvised. Trish brought her computer and showed photographs of fossils and rock layers, and gave an impromptu, informal presenta-

tion to James. Her presentation consisted mainly of photographs and examples from the area surrounding Ithaca. James repeatedly connected her examples to his own experience, whether it was from his childhood or from trips to the waterfalls with his daughter. He was excited to explain what Trish was telling him to his daughter, and was unafraid to ask questions or clarify what she was saying. James showed delight in the ideas he was learning about, as well as Trish's way of expressing those ideas. He liked her whiteboard drawings of geologic formations.

We left the meeting thinking that we would try once again in early January to go to the falls and collect fossils and sounds. But when we spoke in January, James said he had been working with sounds he thought were appropriate, so we simply had another meeting. During this meeting, he brought some equipment and played around with different sounds. Trish gave a more formalized version of her lecture while James worked on several machines to create ambient music and sounds. He said he would just follow her and improvise, as it was a process he was very familiar with. Her lecture (story might be an appropriate word) maintained the hourglass shape they had both felt strongly about, but the piece itself was not what they had originally envisioned, largely due to the weather.

Holly and Spencer

Holly is an entomologist who coordinates the NY State Invasive Species Institute and Spencer is a composer living and working in New York City. Like Itai and Maren, they attempted to follow the prompts very directly. Of the four pairs, they were the only ones who wrote out a mission statement: "To engage the audience in an ecological process—invasion—using sonification. Our in-

tention is to maintain a light, open-ended environment by which people can interpret their own meaning." They had also decided to attempt to create a performance using audience participation. In this case, the audience participation component played a key role in the performance itself, and would become the sole focus for much of their collaboration. They agreed that they would have the audience act as invaders in an environment by making specific sounds. These sounds would drive out other noises made by the natural inhabitants.

Because of this specific goal, they came to the second meeting with a different set of priorities than the other groups. They had already established very clearly what their participatory element would be, and it was highly technical. It involved a computer interface that would receive sound the audience made and use it to determine what other sounds were played. They had agreed they wanted a little help with this, since it was so highly technical, so we agreed to bring a third person to help create visualizations to go with the sonic interface. Nick, a graduate student in Information Science and a computer programmer would help, and he would join us at the end of our second meeting to go over the details.

Spencer's technology was an integral part of their performance, so at times, Holly had trouble participating in the creative process. Schedules were also problematic, and last minute cancellations meant that the pair would not be in the same room again until the day before the technical rehearsal (a rehearsal that all the pairs attended prior to the performance). Only then were they able to talk about the rest of the performance. Technical difficulties in making the

program work further impeded the time the pair had, so the discussions that usually happened during the second or third meeting never occurred.

Due to the technical issues with the piece, much of the substantive discussion about themes and narrative were pushed to the day before, or the day of, the performance. Subsequently, Holly and Spencer were forced to make very quick decisions regarding the performance. While Holly expressed discomfort over these quick decisions, Spencer said he was accustomed to working in such situations.

CHAPTER 4

FROM PROBE TO PERFORMANCE

Each pair's performance was shaped as much by they way they engaged with the cultural probe as it was by the subjects they discussed and the media they used. The probe was meant to be provocative, so there was no "right" way to use them. One of my goals in observing the probe was to see where their needs as creative collaborators would diverge from the tools I had provided. In addition to learning something about the pairs through this process, I hoped to learn something about the probe, and about the role I played by introducing it. The probe was a structured way for the pairs to explore their ideas as well as a means of understanding one another's points of view. It also served as a way for me to learn about the pairs.

Interpreting the probes

As I described earlier, Lyrae and Jim did not follow the cultural probe directions closely, but used the prompts as points of departure for their conversations. Because their fidelity to the activities suggested was low, they were able to reshape the probe to suit their own needs. In the first prompt, they were asked about rituals that begin and end their work, and they agreed that they did not feel as though they really stopped working. This was not a rejection of the question, it was an acknowledgement that the question did not reflect one or both of their worldviews. Because this occurred during the first question, it may have been easier for them to branch off from the "instructions" to continue their own conversations. Lyrae was often the instigator for their departures. She disagreed with the question posed in prompt 3, and Jim responded by saying he did not feel he had the right to reject the prompt, but once she es-

tablished a pattern of departure, Jim appeared to become more comfortable with the idea.

> Lyrae: All right. (reading) Draw an artist or performer...I don't see a difference as quickly as I see similarities. I don't like this dichotomy, it's something I don't buy, the artist is the scientist...
>
> Jim: Okay, that's interesting. Yes, I had the same reaction but I didn't feel entitled to complain. Lets see...
>
> L: Why not? I'm good at calling bullshit. I call bullshit. That's bullshit! Don't divide me from my fellow person.
>
> J: I agree that there are skills sets that distinguish scientists from artists, which would become very clear if you asked me to draw anything.

Jim and Lyrae used the probe as a way to engage, but the design of that engagement was their own. They enjoyed connecting their ideas, and this appeared to come easily for them. Much of the time, they diverged from the prompts altogether and just let the conversation progress from one topic to the next. This way of communicating became central to their collaboration, and the resulting performance was a formalization of this process. They found a way to replicate their exchange of ideas that would allow them to be succinct enough to place in it front of an audience.

Each attempt they made at audience participation also reflected the process they designed. Part of the reason they couldn't settle on a way to engage the audience in a participatory action was that too much background information was required in order for the audience to be able to engage in the same kind of activity.

Maren and Itai also retained experiences they had during the cultural probe and used them directly to design their experience; however this happened in a very different way for them. They did not question the probe in the manner Lyrae and Jim did. Rather, they followed the directions as precisely as they could. They allowed the probe to help shape their conversations, rather than reshaping the probe. When they began to discuss the final prompt (the mission statement for their piece) they went back to each of the prior questions and tried to find a way that their discussion fit into their mission. One example is scale: they were very interested in scale when they looked at the image in Figure 3 so when it came time to write their mission statement, they revisited the concept and found that it was an interesting dimension in their conversation about fruit flies. Maren also worked with the idea of scale as she choreographed her pieces. During the interview at their third meeting, she said that she had choreographed her dances thinking about scale:

> Oh now my foot's the fly. Oh now my body is the fly...I worked a lot with scale. I don't know if you saw this but I had my foot and my two hands and those were the three flies...then all of the sudden now my whole body is the fly so I can play with scale. I don't expect everyone to see that but I thought that was interesting and subliminally that is what makes the dance interesting.

Lyrae and Jim formalized the informal conversation they were having by developing a structure and using their existing body of work to create a kind of script. Maren and Itai did so by incorporating actual spontaneous conversation that occurred during this meeting into their final performance. During the first meeting, when Itai asked Maren if she'd seen a fruit fly, her response was, "Yeah, in my house, during the summer…I kill those things!" The beginning of

their performances was a loosely scripted conversation in which a sound of buzzing was played and Maren pantomimed trying to kill a fly and Itai stopped her, and began to explain the virtues of the fly.

Though Maren and Itai's interaction was very different from Lyrae and Jim's, both pairs made attempts to recreate experiences they had during the probe for an audience, in essence, tying the probe directly to the performance. For Trish and James and Holly and Spencer, the probe was somewhat different. For Trish and James, the probe served as a way to begin their conversation, and initially inspired the shape of their performance (the hourglass); however, when they reached the prompt asking them to create a mission statement, James indicated that he didn't think they'd be getting to the performance during the first meeting. It seemed as though he read the question as a prompt to begin planning the performance. Because they interpreted the prompt as a starting point for planning their performance, the two began a conversation about what they wanted to do, rather than considering the aim of their performance. It seemed as though they had skipped a step the other pairs had taken when they created their mission statements. Trish and James had already decided they would address the hourglass, but they redefined and reinterpreted the meaning of the hourglass several times. Because they felt they already had a thematic focus they went directly to discussions of the performance itself, they reached conclusions much more quickly than the other pairs. Their plan did not fully come to fruition, in large part, due to the cancelled field trip. I asked them if they thought the final project would have been different had they been able to fully execute their plan. Trish said:

> I would have loved to have seen a role reversal. At least on my end. I would have loved to be making the [music].

> Part of that is just the fact that the snow made it so that we couldn't record the sounds so that I felt like I was at least in some way part of the creative process...to me this isn't creative, it's just effective teaching...to have been able to be taught to represent this with noises would have been something that i could have felt like I was really... I feel like the way I feel about the Brachiopod might have been able to make noises... I don't know necessarily. It would have taken much longer...but I think that would have made it more beneficial for me.

Holly and Spencer decided early on that they wanted to pursue audience interaction. When it came time for them to create a mission statement, they immediately began to discuss ways to include the audience, so much of the work they'd already done on the cultural probe was set aside. Though they returned to some of their conversations, for them, the rest of the process became about planning and executing a very technical, very complex performance. Due in part to Spencer's distance from Ithaca (he had recently relocated to New York, though still technically a graduate student at Cornell), and in part to rescheduling due to illness, their second and third meetings were a bit rushed and manic. The addition of another collaborator to help them create the visualizations also helped establish a need to spend their time and energy addressing practical and technical concerns.

Technological determinism and the creative process

Holly and Spencer began their second meeting discussing the kinds of sounds they wished to use for the invasive species. The invaders were to be played by the audience, and Spencer suggested they needed a sound that was easy for the audience to make. As they began to consider different musical options,

Spencer explained that he would use a program called MaxMSP to create the sonic interface that would pick up the audience sounds. It was evident that he had been planning the project with this software in mind, and when he began to describe it to Holly, the nature of their conversation, and ultimately, their performance, became tailored to fit the constraints of the program.

> Spencer: ...If we write a program, a little program to do this...In Max MSP, it's called Max MSP, it's an interactive environment that can process things in real time. So the sounds, or rhythms. And it has a number of tools that help identify things like pitches or rhythms. So, what I was thinking is, what would be really simple, is a, like, a little bird call type thing. Like three notes that every, that even little kids can do, where it's on a specific pitch, searching for a specific note, that the computer is really gonna recognize, and if you have repetitions in there—If you get the note right, it doesn't care what octave it's in, it can look at all the different octaves—And what I'm imagining is we have that call, and when the computer sees, or when the program sees that those pitches are activated it will...play back us having prerecorded sounds of the call ourselves.

Spencer described the program very early in the second meeting, and he had a very clear idea of how, technically, the piece would work. The result was that this meeting became more of an exercise in creative problem solving than brainstorming. Holly provided some basic information about invasive species and their impact on environments, which Spencer used to create the computer interface (with the help of another graduate student, Nick, who designed the visual component). Holly's input was largely given in response to specific

questions Spencer asked as he worked out how the program would execute their idea.

> Spencer: The question I have is from the scientific standpoint, what, given this process, why do you wanna, what do you see needing to modify, to be more accurate, more truthful during the process? What kind of data do we actually want to use physically in the model? So, for instance, I can read a line, I can read a graph—I can read inputs, so we can set thresholds or limits along the way, you know, say if it's more of a categorical thing…
>
> [Holly explains several ways species are introduced to an environment]
>
> S: Everybody's making different sounds, and what we could do, in order to isolate the sound for the machine is we can have a number of mic inputs in different parts of the room that can pick up pitches more accurately, so like, say like 5 mic inputs scattered about, and then we can hope, with directional mics, so we really get a focused area of the audience, and if we, if the machine manages to lock in, which it probably will, eventually, to some correct pitch in that spectrum, then it will repeat it, and the audience will clue in, and it will start syncing, is that intuitively what you are thinking about?

Spencer's use of relatively sophisticated and uncommon software created a unique dynamic for the pair. Actor Network Theory (ANT) considers the ways both human and non-human actors influence knowledge making (Latour, 1988, 1996). Similarly, Spencer's use of technology introduced non-human

actors into the collaborative process. MaxMSP played such a large role in the process that became an additional collaborator.

In most cases, the scientist speaks a highly technical language, which requires years of training to understand. The artist, on the other hand, has a specific language, but it is more accessible than the scientist's. In this case, Spencer's constrained language was also highly technical, and therefore difficult for Holly and me to understand.

Because much of the project was determined by a technology in which Spencer was an expert, there were some communication challenges for the pair. While these difficulties were challenging for the participants, an interesting development resulted: at the technical rehearsal, Spencer and Holly realized they had slightly different interpretations of the process. Specifically, Spencer had determined that the audience must find specific pitches in order to trigger the program to add 'invaders' to the audio and video. He indicated at the rehearsal that these pitches were to represent "mating calls," which was very problematic for Holly because this did not match the scientific understanding of invasive species. Though the invaders and the rest of the beings in the environment were abstracted shapes and sounds, the trajectory at which they would reproduce and affect the environment came from real data. Since the abstracted representation mimicked reality, Holly was not comfortable with this element of the performance being inaccurate. Part of her hesitation stemmed from the fact that she knew there would be other entomologists in the audience, and she felt an obligation to be as true to her work as possible. After some consideration she told Spencer and me that the piece still made sense because an invasive species must have just the right conditions

to be successful, and for the audience, finding the right notes meant finding the right kind of food and shelter to reproduce and thrive in the environment. This explanation was then inserted into the performance itself.

The use of this technology transformed the project from a musical, or sonic, interpretation of invasive species into something that would fit the parameters of the program. Because the program could recognize different pitches easier than different rhythms, the invasion was based on pitch. In order to allow audience members to make pitches loud enough or clear enough for the program to recognize, some kind of tool would need to be used. This need led Holly and Spencer to think of toy instruments. The slide whistles, perhaps the most unique and distinguishing aspect of the performance, were a result of the constraints of MaxMSP.

Though James also used unfamiliar technologies for making music, it did not seem to have the same role of shaping the collaboration and the performance the way it did for Holly and Spencer. That is not to say that James did not think in terms of what was technologically achievable when he was planning with Trish, because he did. Much like Spencer, James explained what was possible to Trish, and in the third meeting, he brought some equipment to give her a sense of what he could do. Perhaps the difference between the two was that James and Trish spent their second meeting discussing Trish's work, and what, in James' opinion, was interesting and important about it. He often considered what she was saying in terms of how he would explain it to his daughter, and what she would think, and he related it to his own experiences.

Their second meeting was reminiscent of my early work on *Happy Hour at the Event Horizon* in that there was much more of a straightforward presentation

of Trish's work followed by a discussion of how it should be presented. Trish brought photographs and we hooked her computer to a projector to show them. She stood as she presented the photographs, and used the whiteboard in the classroom to draw what she was trying to explain. James, sitting in front of the projection screen, listened intently and asked questions. He showed enthusiasm for what he was learning, and made a strong connection between her description of the geophysical history of the Earth and rhythm in his music. He then went on to develop ideas for music for their third meeting.

James' use of technology seems to be part of his identity as an artist, but it was Trish's explanations of paleontology that were the driving force behind their performance. However, for Holly and Spencer, the program played a larger role in shaping the performance than Holly's data. Holly's data certainly influenced the way Spencer used MaxMSP, but MaxMSP also determined what data was used and how it was used to engage the audience.

The birth and death of audience participation

While three of the pairs, Maren and Itai, Lyrae and Jim, and Spencer and Holly, all wanted to incorporate audience participation into their project, Spencer and Holly were the only ones who had a participation component in the end. Why did they each come to include the idea? And why did only one group incorporate participation in the end? I believe each group had a separate reason for wanting the audience to participate, but I also think that the final prompt, "Write a mission statement for the piece you will create. What will it do? What do you want the audience to think about?" may have played a role in their consideration of the audience. While all pairs read the prompt aloud, these three pairs all did so repeatedly, and specifically addressed the question

of audience. For Lyrae and Jim, I believe there was a strong desire to lead the audience through the same experience they were having. They kept trying to replicate their own process in various ways, ultimately trying to get the audience to make the same kind of connections they were making.

Maren and Itai began to think about the audience during their mission statement. Maren pointed out that their discussions largely revolved around questions, and wondered if they could prompt the audience to think of questions.

> "We pretty much asked alot of questions, don't you think?...If we somehow could shape it around that, that would be interesting. Like, using questions instead of like. 'This is our idea, and this is what we want you to understand.' That seems kind of boring, don't you think?"

This moved the pair in the direction of audience participation. Their conversation turned to creating an experience, and, Maren suggested something "interactive." Itai responded, "So you're trying to bring something from the outside into human experience...How would you do that through dance? Choreography of people. We could choreograph people to get them to experience something."

The participation aspect of the performance was eliminated as Maren and Itai realized that time constraints made it difficult for them to get the audience up and moving. Additionally, it seemed to me that they never came up with a clear idea of what the audience was to do. Spencer had talked about wanting to include the audience before beginning the project. Because he had the idea coming into the project, he suggested right away that the two of them make the audience the invasive species. Early in their discussion Spencer

asked if Holly was interested in “giving people the opportunity to experience what it would be like to be an invasive species.” The two liked the idea and went on to make a specific plan for how to achieve this. This very tangible plan allowed them to design their performance around the audience participation, rather than trying to fit audience participation into their performance plan. This was very different from the conversations in which Lyrae, Jim, Maren, and Itai had engaged. They had all talked about what they wanted the audience to experience, but did not come up with a plan for how this would happen before they planned the rest of their performance. For Lyrae, Jim, Maren, and Itai, the audience participation component would have to fit into an existing framework. Holly and Spencer had the luxury of designing a participatory component first, but the price they paid for audience participation was that they had to try to develop a performance that would fit into the experience they had designed for the audience.

Whatever the reasons for wanting to incorporate participation in the first place, the pairs that were not able to do so in the end seemed satisfied with their work. Even Lyrae, who seemed adamant at first, appeared content without the participatory element by the end.

Lyrae wanted the audience to talk to one another, Maren and Itai wanted them to ask questions, and Spencer and Holly wanted to create a fun and engaging experience. I think these three pairs may have been drawn to audience participation because they hoped to differentiate their performance from a lecture. Even though only one group incorporated direct engagement, I consider the fact that they were all drawn to engage their audience as an encouraging sign

that artist/scientist collaborations have the potential to help scientists communicate with the public.

Ultimately, I think audience participation is likely the first thing that comes to mind when trying to engage audiences, so for Lyrae, Jim, Maren, and Itai, it may have been important to them when they began their process, but for their final product, they found other ways. Maren and Itai hoped the audience would be provoked to ask questions, or to think about the questions they were asking when they created the piece; Lyrae and Jim added the “annotated” third reading of their conversation in hopes that the audience would engage with some of the connections they were making.

CHAPTER 5

DEMARCATION AND BOUNDARIES

The cultural probe encouraged the pairs to consider the roles of science and art in some ways they had considered before and others they had not. Particularly, prompts 4 and 5 asked them to consider the nature of the relationship between science and art, and to identify images as science or art. The quotations given in prompt 4 and the images shown in 5 were open to many interpretations, and each participant had unique views on these subjects. In addition, questions about their own work habits and career histories enabled them to define their roles within their fields, and, more broadly, within the context of the culture in which they lived. Because they were asked to consider these questions, and in effect, to consider the value of their discipline and their work, many of their conversations turned to boundary work. In this chapter, I will I discuss boundary work in the sense that Gieryn (1983) writes about it, and I will expand his discussion of boundary work to the fields of science and art, as well as the professions of the artists and scientists.

Boundary work in art and science

Science and "not science"

The problem of demarcation in science has been widely discussed by scholars in the sociology of science. Popper famously asserted that all science was falsifiable. His demarcation of science in this way was an attempt to separate science from religion and superstition, but this is not the only demarcation drawn to understand "what science is." Though sociologists often take up this problem, it is common for scientists and science communicators to engage in

boundary work, and for them, the demarcation of science and non-science is flexible and ambiguous, often because there are several forms of non-science they feel warrant boundaries. Two of the most obvious ways scientists engage in boundary work are in the demarcation between science and religion and the demarcation between science and technology. These different forms of demarcation serve to expand authority into new domains, to monopolize authority, and finally, to protect autonomy (Gieryn, 1983, pp. 172-173).

During conversations with Maren, Itai attempted to establish the boundary between science and "not science" with the idea that science is an attempt to understand something that would exist without our trying to understand it.

> I mean in some sense science is going after something that would be here independently of people...so there is a world independent of people. Physics goes on; gravity still works whether we're here or not, so there are things that go on that are independent of us, and science in some ways tries to ask about those things.

While he was acknowledging a "real" world, he was careful not to use the word "real" or to imply that science could understand that which exists without us. He often referred to science as a social endeavor. His language shows a bit of a struggle between the critical rationalism of Popper's demarcation of science as falsifiable and the kind of social construction of scientific knowledge explored by Latour and Woolgar, among others (Latour & Woolgar, 1986). He tells a story about two physicists, Oldsman and Mach, who had different ideas about the physical properties of the universe. Oldsman believed the universe was composed of atoms, while Mach believed the universe was continuous. For many years, Itai said, people believed Mach, which drove Oldsman to sui-

cide. But ultimately, he said, there was a right answer, no matter how popular Mach's ideas or how anguished Oldman was. In Itai's words, "...there are parts of [science] that are very rooted in social behavior and parts of it that aren't: that are sitting back and telling you who's right, and that's really powerful." Itai's discussion of science as a social endeavor shows that he was engaged in a very nuanced kind of boundary work to maintain the authority of science.

Holly's view of science was very close to Popper's, and when discussing how she went about doing her work, she alluded to the scientific method, in which hypotheses were formed and tested. She said that before she began working within the scientific method, she kept a large pad of paper in her office, and used this pad to scribble ideas and inspiration for her work. This clear distinction between the inspiration for her work and the scientific method reflects Popper's idea that true science is always deductive, but that the inspiration for a hypothesis came from somewhere else; that there is some ineffable quality or spark of creativity prior to, and separate from, the work of science (Popper, 1959).

Much of the discussion of science followed Gieryn's description of methods of professionalization. Itai identified the relationship to nature, while Holly identified the protocols of science. It seemed as though the artists paired with the scientists were fairly familiar or comfortable with the boundaries established by the scientists, and did not challenge them. Though for the most part, the same is true of the scientists' understanding of the demarcation of art, the boundaries seemed a bit more nebulous.

Art and "not art"

> Because expansion, monopolization and protection of autonomy are generic features of "professionalization," it is not surprising to find the boundary-work style in ideologies of artists and craftsmen and physicians. (Gieryn, 1983, p. 172)

While discussions arose about the demarcation of science from non science, there was also a need for boundaries between art and "not art." When looking at the photographs in prompt 5, Jim was the first to engage in boundary work between art and non-art. When he and Lyrae saw the image in Figure 6, Lyrae expressed dislike for the image but did not know why. Jim's response was, "I don't have any strong views about petri dishes; I like to think that taking pictures of nice looking things is not the same thing as art."

Figure 6: Image from prompt 5 Artist Amy Chase Gulden and scientist Kristin Bladwin painted E coli on to a petri dish to make natural forms.

James had a very different view of the boundaries of art from non-art. His work, both as a visual artist and a musician, is highly abstract, and often created with materials and sounds not usually associated with the arts. For example he has created soundscapes using kitchen utensils and various household objects. James indicated that to him, intention was a large part of what separated art from non-art. He also thought art was moving toward abstraction, and that as an artist, that is the direction he wanted to push his work. He explained his process as an artist:

> As scientists help us understand and know more, the art shouldn't be getting smaller and more concise. Everything we know fits together abstractly, I just see art getting more and more abstract, and that's one of the things I try to reach for, how far can I go and still understand what I'm doing...I don't care if anyone else understands as long as I still understand what's going on.

James placed the distinction between art and not art in the process, rather than the product, an interesting distinction. It may be natural that Jim identifies the demarcation of science in the process and art in the product, while James may hold the opposite view because they understand their own work as a process, but appreciate one another's as a product.

A large part of boundary work within the arts is the establishment of aesthetics (Becker, 1984). That aesthetics are socially agreed upon constructions is much more widely accepted than the idea that knowledge is constructed. Within each artistic movement or community, or, as Becker calls them, art worlds, aesthetics are established to distinguish art from non-art, as well as good art from bad art. Each art world, therefore, will have its own demarcation

for art and non-art. Moreover, the evolution of art worlds will dictate that eventually an artist who belongs to an art world will create something that does not belong within that world, and will thus join or begin a new art world. These boundaries of art, then, are much more fluid than those that demarcate science from non-science.

Science and art

While Gieryn discusses the demarcation of science from both pseudoscience and mechanics, my pairs sought to establish the boundary between science and art. These conversations usually arose again during prompts 4 and 5, in which the pairs were reacting to quotations made by famous artists and scientists, and were asked to classify ambiguous images as either science or art. While Itai and Maren found common ground in process, Itai would return again and again to what set science apart from art. This demarcation was, in part, a response to a conversation about the similarities in process between science and art. It seemed necessary for Itai to draw a clear distinction between art and science, regardless of how much similarity he found in the processes. Even during their interview at the third meeting, Itai was trying to work out how to think about the similarities that had been discussed and the boundary between art and science.

> So there are parts of it that are very rooted in social behavior and parts of it that aren't, that's sitting back and telling you who's right and that's really powerful. You look at art: when Picasso invents cubism, nobody likes it because they're not used to it, does that mean it's not great? Because then after a while people get used to it and all of a

> sudden critics hail it and it becomes great. So how do you define greatness in that same sense of objectivity…

I believe that his distinctions were a part of the professionalization process Gieryn describes, but the fact that this kind of boundary work takes place not just in distinguishing science from its less "valid" counterparts like pseudoscience, but also from other legitimate fields like engineering or the arts indicates there is something more happening here. Irwin (1995) discusses the prevalent belief in science as the ultimate form of progress. Science, in some ways, enjoys a privileged place in our culture, and part of professionalization for the sciences is maintaining that place.

Though I don't think the end result of the boundaries Trish and James established is vastly different from Itai and Maren's, the boundary itself is. Trish and James drew what seemed to be a temporal boundary between art and science. In their hourglass representation of art and science, the two met in the middle, but the process began with science asking big questions and funneling information into specific answers, which artists then made meaning from by exploring the broader implications of the answers science provided. They did not find an overlap in process so much as a reciprocal relationship in which art and science were of use to one another, related, but not a single entity.

Demarcation of fields within science and art

In addition to the need to demarcate the lines between the fields of art and science, the pairs also discussed boundaries within the different disciplines in each field. Within the arts, Itai confused acting with dancing. "They're the same thing, right?" he asked when Maren suggested she was not comfortable acting. The remark drew laughter from Maren, myself, and others in the room,

but for Itai, there was no clear demarcation, because these were two aspects of performance. In a sense, Itai was right. Dancers are expected to convey emotion with their bodies and faces; however, our reaction indicated a clear delineation between the two that was commonly understood by practitioners in the arts.

This is an example of how Becker perceives art worlds are formed, though he readily admits that these boundaries are not easily understood by sociologists who study them or by practitioners within the art worlds themselves. “Both the ‘artness’ and ‘worldness’ are problematic because work that furnishes the starting point for the investigation may be produced in a variety of cooperating networks and under a variety of definitions” (1984, pp. 36-37). The boundaries of these worlds are constructed within these networks, and they are constantly changing.

It seems there are more rigid demarcations between the different fields in the sciences; however, there, too, one can find different schools of thought. Within the field of chemistry, for example, there is a further classification of organic chemistry. The majority of science is shaped in research institutions like universities, so even though scientific concepts like entropy cross several disciplines, the structure is much more solid than that of an art world, so it is less likely that this kind of conversation would take place regarding scientific disciplines.

My experience with the sciences is that different disciplines respond differently to the idea of collaborating with artists. Because I received much more inter-

est from physicists than scientists in any other field[2], I asked both Itai and Jim why they thought physicists were more likely to sign up for projects like this. Itai felt there was an inherent difference in the personalities of physicists and other scientists, and that physicists were likely to be more artistically inclined than other scientists. Jim's response was that he thought physicists felt that their work encompassed all the other sciences and was, in a sense, more important that the other sciences. This interest among physicists merits further inspection in the future, because if there is indeed a difference in what fields are more willing to work with scientists, it might shed some light on their interest to communicate their work to a broader audiences.

Within the boundaries of art and science

Though there were many lines of demarcation in these conversations, the pairs found several common threads between art and science as well. Each of their assessments of art and science might look like a Venn diagram, but some would find a greater overlap than others. This area of overlap was not only a different size, but encompassed different aspects of science and art. For Maren and Itai, one of the commonalities between art and science was the need for open questions.

> Itai: When you have a good sculpture, it's obvious. And when you have a good science project it's obvious which question you are answering...I don't know, the questions are the things that are the most important for me.

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[2] The same was true during my time as a practitioner, in fact, *Happy Hour at the Event Horizon* was not originally envisioned as a play about particle physics, but the response from physicists overwhelmed the other disciplines, and we decided to narrow the focus of the show.

> Maren: I agree. I think when you ask a question you're more open to letting answers come to you, and then you are more able to go to a place you might not have expected, and that's something that's new.

Similarly, James felt that a goal of both art and science was to make people think, though James added that art also made people feel. James and Trish also compared biology to art, when they were looking at the petri dish image (see figure 6). Though Jim and Lyrae didn't care for the piece, Trish and James felt that it exemplified what they thought of as the random beauty of both science and art.

When asked to draw an artist and a scientist (shown in Figure 7), Spencer drew very similar figures. One was composed of musical notations and the other of mathematic symbols. He said this was because both art and science were both "meaningful, symbolic languages." Itai also said that there was a kind of linguistics in both art and science. Though the artists in each pair usually brought up the similarities between art and science (Itai is an exception), the scientists generally agreed with their analysis of the similarities.

Legitimization and professionalization

In addition to the boundary work done to decipher science and "not science," art and "not art," there were demarcations between artist and "not artist," and scientist and "not scientist." These questions about what made one a legitimate member of their chosen profession were complicated, and like the boundary work done above, proved fluid when participants needed to represent different interests and experiences.

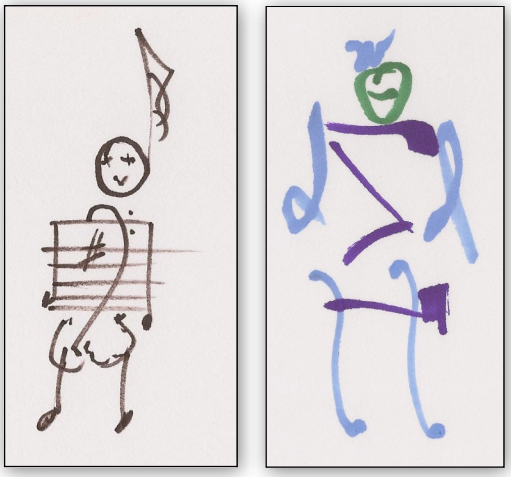


Figure 7: Spencer's drawings of an artist (left) and scientist (right).

Perhaps the clearest example is the difference between the ways in which Holly and Trish viewed themselves. Both had completed graduate degrees in science: Holly received a PhD in entomology and Trish an MS in paleontology. Foreseeing possible questions during recruitment, I specified self-identification as an artist or scientist as a measure of qualification for the project. Holly told me during the first meeting that she had not been sure if she would qualify for the project or not until I mentioned self-identification as the criterion for involvement. Her reasoning was that she was not currently engaged in research, but was coordinating research for the Invasive Species Institute. Trish, however, was very comfortable identifying herself as a scientist, citing her degree as evidence. Her title at the Museum of the Earth is Evolution and Global Change Projects Manager, and while her job has a research component, she does a good bit of public communication and organization. Certainly she doesn't fit the description Holly first offered of a scientist as researcher. Why did these women have such different views of whether they were scientists? One reason may be the different demarcation criteria in their respective fields. It may also have to do with the nature of Trish's job: she still does field

work, even though the majority of her time is spent at a desk, and the majority of her daily tasks and projects are administrative rather than research oriented. On some level, this is much like a physicist who runs a lab, but no longer does experiments her or himself.

Feelings of legitimacy were even more pronounced in the arts. When completing the prompt in which the pairs were to tell the story of their career in newspaper headlines, James titled his final headline “Man finds courage to call himself artist.” The title, he said, revealed how difficult it was for him to call himself an artist, even though his work had been shown in galleries.

It seems that the lines between science and “not science” are different from the lines between scientist and “not scientist,” but the lines between art and “not art “and artists and “not artists” overlap somewhat. Though in both cases, the sciences seem to have found a more established method of demarcation, in both cases these lines are flexible, and often personal. Emotion often plays a strong role in the boundary between professional and non-professional.

Generally, it seemed that it was harder to establish legitimacy within the arts than the sciences, which is most likely due to the academic structure embraced in the sciences. There is no clear or defining system of credentials in the arts. In some cases an advanced degree helps, in others, it hinders. Each art world, then, generates its own concept of what a professional looks like, just as each art world generates its own aesthetic rules. Professionalization in the sciences in not quite as clear cut as it would appear, however. Holly and Trish’s very different ideas of what makes a professional scientist indicate that though there is a clear system in place, there are differences in the perception

of legitimacy in the sciences. It is unclear whether these discrepancies fall along disciplinary lines or arise from other circumstances.

The value of boundaries

Though boundaries were malleable and changing within the project, they played an important role in shaping the conversation. Even though boundaries were flexible, or even unknown, they were central to the participants. It seemed as though establishing boundaries helped them to be free to work together. Either because they had a clear sense of what they were doing and were not doing, or because once they established the boundaries, it was easier to disregard them somehow.

For Jim and Lyrae, it became a matter of how to name what they were doing, and so, how to understand it. Early in the process, I referred to their conversation as a poem, and Lyrae was very quick to correct me. Just as Jim said that art was more than just something pretty, Lyrae made it clear that poetry was more than a string of words and phrases put together. She emphasized rhythm and meter, saying that even when a meter wasn't consistently used in a poem, the poet had still carefully considered meter. Once the title of "conversation" had been given to the product of their collaboration, the way they would present it to the audience was much more clear for Jim and Lyrae. Additionally, once their project had been labeled a conversation, Jim was visibly more relaxed than he had been before. He said he had been nervous about creating something worthy of the title performance in such a short time, and after each step in the process he said he was "less terrified" than he had been before, but the title of conversation seemed to be what most put him at ease.

Once Maren and Itai had established some boundaries, they began to think about the project in terms of a “fair” representation of dance and physics. They wanted to make sure that the audience got to learn as much about dance as they did about physics. Both seemed equally as interested in fairness, and though Itai’s scientific explanation took up more of the time, they seemed satisfied that they had given equal weight to each section. The boundary work helped them assess the fairness of their performances. Although the boundaries had very different functions for different pairs, each pair needed them in some way. Establishing boundaries became a necessary part of the collaborative process.

CHAPTER 6

LANGUAGE AND TRANSLATION

Though boundary work proved necessary for each of the pairs during the first meetings, once boundaries were established the pairs would have to find ways to cross them in order to work together. Due to highly specialized terminology, often neither of the participants in each pair had a language to talk about the other's work. While Jim had a kind of understanding of iambic pentameter, if asked, he would not have been able to define it without help. Likewise, Lyrae would not have understood what a blue phase was without assistance from Jim. Translation was not, however, simple a problem of terminology. The pairs needed to find ways to express complex ideas and concepts in languages their partner could understand. Most translation efforts took the form of either visualizations or metaphors of the concepts in need of explanation.

Holton (1996) lists the visual imagination, the metaphoric imagination, and the thematic imagination as three important tools of science. While he did not necessarily specify these as communication tools (and their use is not restricted to communication alone), he finds that science often begins with visualization because, "...early Western science made its debut through the eye" (p. 161). This propensity for visual communication is acknowledged by many, including Dondis (1973), who discusses a "visual bias toward information" (p. 2) that is present from childhood. Both the arts and sciences rely heavily on visual information not only in their products, like paintings, but also in the planning and execution phases. Einstein said that, "The words or language, as they are written or spoken, do not seem to play any role in my mechanism of thought. The psychical entities which seem to serve as elements in thought

are certain signs and more or less clear images which can be voluntarily produced and combined" (Holton, p. 170).

As for the metaphoric imagination, Holton recounts instances of the use of metaphor in important discoveries in the history of science, but acknowledges there is a risk in using metaphors.

> The Dictionary of Modern Thought still says of metaphor and analogy that they are "a form of reasoning that is particularly liable to yield false conclusions from true premises." Metaphor has been called the "essence of poetry;" it works through illusion. And surely, the business of scientists is precisely the opposite. Metaphor and analogy might therefore seem to be what scientists should most assiduously avoid. (p. 176)

As Maren and Itai worked on their project, they became acutely aware of this tension between truth and expression in metaphor as well as in visualization.

When discussing the quotations in prompt 4, Itai added one of his own: “Art is a lie that tells the truth,” which he attributed to Picasso. He talked about some of his own work in these terms.

> But I'm just taking some representation—it's a lie, in some sense—some representation of the real thing. And trying to get some deeper truth by simplifying this thing into some sort of structure that I can then, you know, attribute to that.

Later he brought up this quote again, specifically in reference to the composite video he’d made of the fruit fly (which he referred to as “Frankenfly”). Itai believed that letting go of some of the specific facts of the fly, like its exact shape,

allowed him to find something else that was more important to him, like the way the fly turned when in flight.

> If you want to convey motion in a sculpture, you might not do the anatomical thing and have a horse with four legs, you might give it 1000 legs, to make it look like its moving...So the point is, you tell a lie. And so now you as a scientist are collecting data, and data is only part of the story. Maybe I take an X-ray of something, and I see a structure, but that's not everything that exists in the material...But I'm just taking some representation, it's a lie, in some sense, some representation of the real thing. And trying to get some deeper truth by simplifying this thing into some sort of structure that I can then, you know, attribute to that. Something that's not anatomically correct, in order to tell the truth.
>
> Like the idea that an artist, you know, like I said, will tell a lie to tell the truth, right. So a scientist will have to distill what they see from the real world, and come up with the elements, the threads they think are the core of what is going on. And in art, you might do the same thing, you might simplify the bull into three lines in order to get at the core of what is bullness. I don't know why I'm picking on Picasso.

It seems, then, that by allowing himself to use methods of translation which he considered “lies,” Itai was able to make imaginative leaps in his work and perhaps to find things he would not have seen by observation alone. In this sense, these translations transcended their original purpose, which was to find a way of expressing a concept. They were a way to understand and develop concepts as well.

The horse with a thousand legs Itai spoke of is a translation of movement through time (specifically, the movement of a horse running) into a two dimensional visualization. This visualization can be universally recognized as motion, even though there is no real world equivalent of that representation. In other words, it cannot be seen when observing a horse running, but tells the story of a horse running without the need for movement, and thus, without the need for time to elapse. Itai may have been speaking of Muybridge's (1957) photographs of horses in motion, which were series of horses moving so that you could see each individual movement. While Muybridge did not take the next step and combine all of these motions into a single image, his images, as

Figure 8: While Itai cited Picasso, Duchamp's Nude Descending a Staircase, No. 2 (1912) is one of the most famous instances of the kind of visualization he is describing.

well as the technologies he used, inspired those who did. One of the more famous examples in painting is Marcel Duchamp's Nude Descending a Staircase, No. 2 (1912). This famous painting (shown in Figure 8) may not easily be recognized as a work with scientific merit; however, it does have a scientific equivalent. Etienne-Jules Marey began to work with chronophotography in the 1880s. This work has a significant place in scientific visualizations because it represents a step away from what is visible to the senses. This break from the senses, and Marey's dissatisfaction with them, came about because of the development of processes that led to images that were only visible only through their inscription, things that only exist in the reproduction the machine makes. This represents a shift in our understanding of visualization. Marey referred to these images as ways of educating sight (Marey, 1895; Snyder, 1998). Put more strongly, he spoke of the devices that made these images as ways of overcoming the imperfection of human senses. The "lie" in these images is

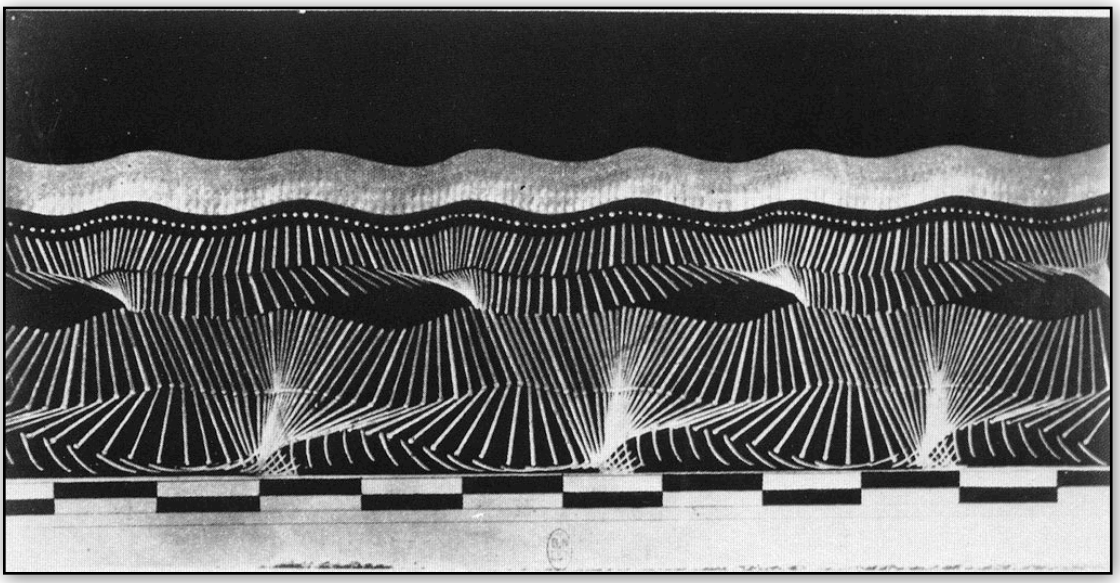


Figure 9: A chronophotograph of a man in a black suit with lines along the side. Taken by Marey some time around 1882.

that they are not “real” in the sense that we can perceive them with the human eye.

While both visualization and metaphor can be perceived as “lies,” they also provide insight in a way that nothing else can. For the pairs, visualization and metaphor were often the best, if not only, methods of communication that would allow them to speak a language the other could understand. They used various successful methods of visual communication as well as various types of metaphor and analogy to discuss their ideas. While convention may still allow us to call these things lies, they do not communicate falsehoods, so it was very interesting to me that Itai still used this phrase.

Visualization

The visualizations created and discussed by the pairs fell into two categories: those that represented physical concepts (like Trish’s drawings of fossil creatures) and those that expressed abstract ideas (like Trish and James’ hourglass and Itai and Maren’s process circle). These two categories roughly align with Galison’s (1997) distinction between homologous and homomorphic images. Homomorphic, or mimetic, images "preserve the form of things as they occur in the world" (p. 19), while homologous images illustrate "the logical relation among events." In a review of Galison’s book, Elkins (1999) asserts that there can be no purely homologous or homomorphic images, but rather that these distinctions represent ideals rather than specific images.

> Looking at premodern representations I would consider the properties Galison names as homologous and homomorphic to be ideals rather than markers of traditions; and I would add that there are other namable traditions just as

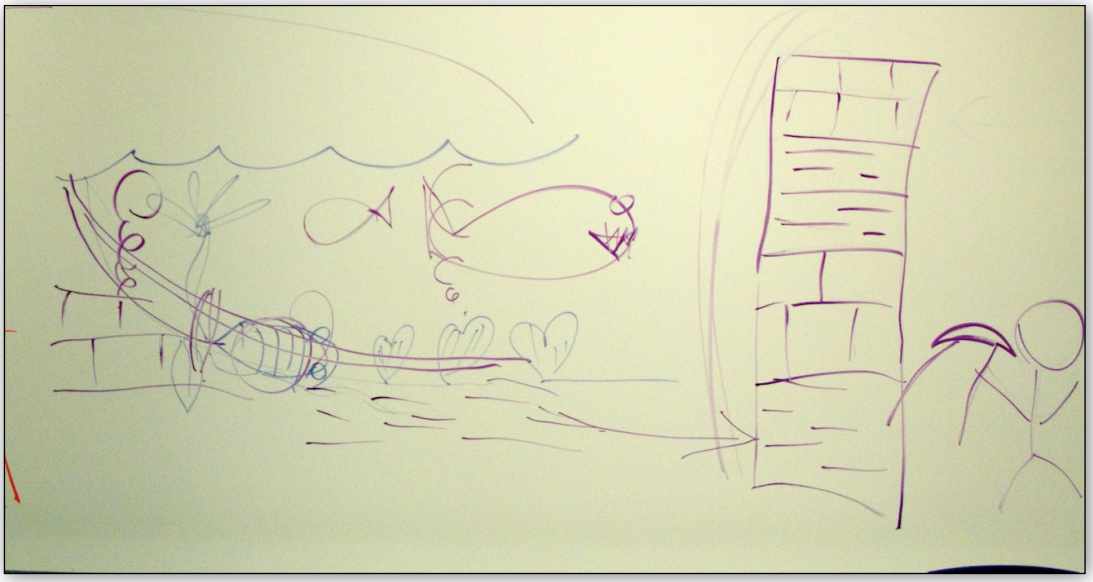
> robust and consistent. Homologous and homomorphic are therefore characteristically twentieth-century concepts, rather than properties of representations in general. (p. 8)

Dondis (1973) delineates three types of visual recognition, the representational, the abstract and the symbolic. "Each level...has its own unique characteristics which can be isolated and defined, but they in no way conflict. In fact they overlap, interact, and enhance the individual qualities of each other" (p. 82). Representational information is literal, easy to understand information, like that found in photographs. Abstraction often allows for an "uncommitted exploration of a problem" (p. 82), which Dondis says is attractive to artists because of its purity. Finally, the symbolic level ranges from simplified images to complex language systems.

Visually representing space and time

During their performance, Trish drew the story she was telling. Her drawings had a rough, technical feel to them, but they were still sketches of the history she was explaining. She combined technical geologic representations with humorous interpretations and physical representations of real objects in the world. There were several iterations of these drawings, and through them, she developed a set of conventions she could incorporate into the performance.

Here I will discuss one part of these visuals, leaving out her drawings of the big bang and the formation of the earth. At the point she began the drawing captured in Figures 10 and 11, she was discussing the formation of sea life during the Devonian period. First, she drew the trilobite and its environment, then the subsequent destruction of the environment due to a small earth-



Figures 10 (top) and 11 (bottom): Trish's drawings of the Devonian Sea.

quake. She then began the second part of her story, in which she talked about the work of a paleontologist digging into a rock to learn about this trilobite. When creating this presentation, Trish blended technical drawings she was taught to use in field notes with improvised additions that were meant to add something with which we could identify.

Trish was simultaneously drawing on the representational, abstract, and symbolic levels. The symbolic aspects of her drawings were the technical symbols for the types of rock found in Taughannock Falls: limestone and shale. While these symbols contained scientific information, they also helped James and me, and subsequently the audience, understand the properties of the rocks. To situate these technical drawings in a location with which we were familiar, Trish drew the falls coming off the top of the rocks, blending representational and abstract sketching with symbolic, technical drawings. Finally, when she reached the end of her story, she connected the image of the Devonian sea

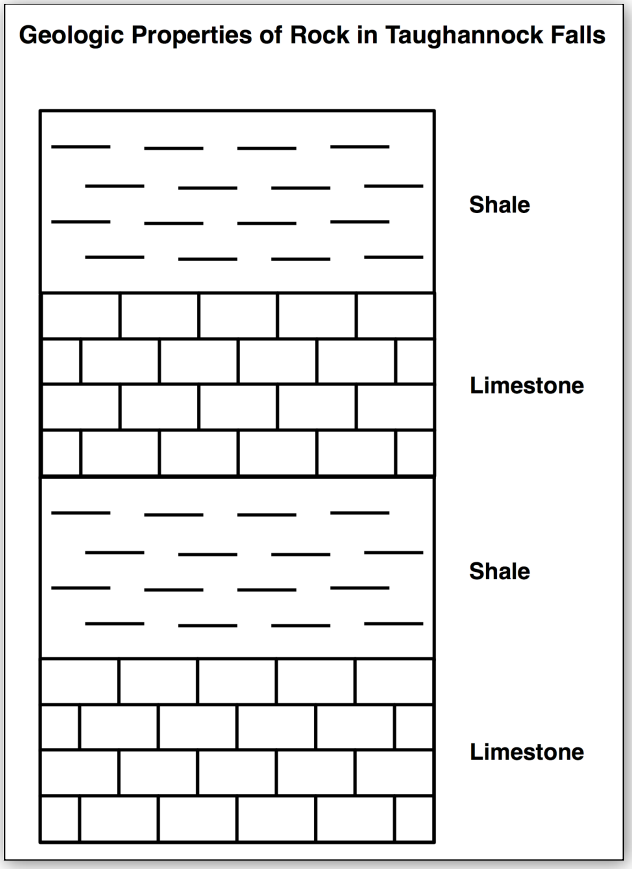


Figure 12: Reproduction of Trish's technical drawings of the types of stone found at Taughannock Falls.

with the image of Taughannock Falls by extending the line that indicated the sea level over to the falls, indicating the water at the base of the falls.

This simple line showed the passage of millions of years. Though it was a very different strategy from Marey or Duchamp's representations of motion, it also visually represented changes in bodies over time; something that is not visually perceptible. Though she drew only a single line to connect the ancient and unfamiliar sea with the familiar landmarks her audience would know, the representation effectively provoked James and me, and I would imagine some audience members, to imagine the falls as an ancient sea. For me, the line connecting those two drawings inspired a deep understanding of the geological history of the falls. I asked Trish whether she had planned or intended to do this, and she had not. It was spontaneous, as was drawing the falls on top of her diagram of the rock formations. These spontaneous additions to the scientific information are the things that made the information accessible to us.

According to Dondis (1973), humans have a gestalt response to abstract visual messages.

> The meaning inherent in abstract expression is intense; it short-circuits the intellect, making contact directly with the emotions and feelings, encapsulating the essential meaning, cutting through the conscious to the unconscious. (p. 22)

Dondis' assessment of response to visuals is based in gestalt psychology, Pomian (1998) finds the same immediate emotional connection through vision throughout history.

> Ancient theories of vision differ one from another. But they all agree that to see an object is to establish with it an immediate relation such that nothing qualitatively different from the soul, on the one side, and from the object of vision, on the other, could find itself between them. (p. 211)

The hourglass

Some of the most intriguing examples of visual translations occurred in Trish and James's work together. First, the visual metaphor of the hourglass the two came up with during their first meeting was used as a guiding principle throughout their work. When they were working out what to do next, or how to

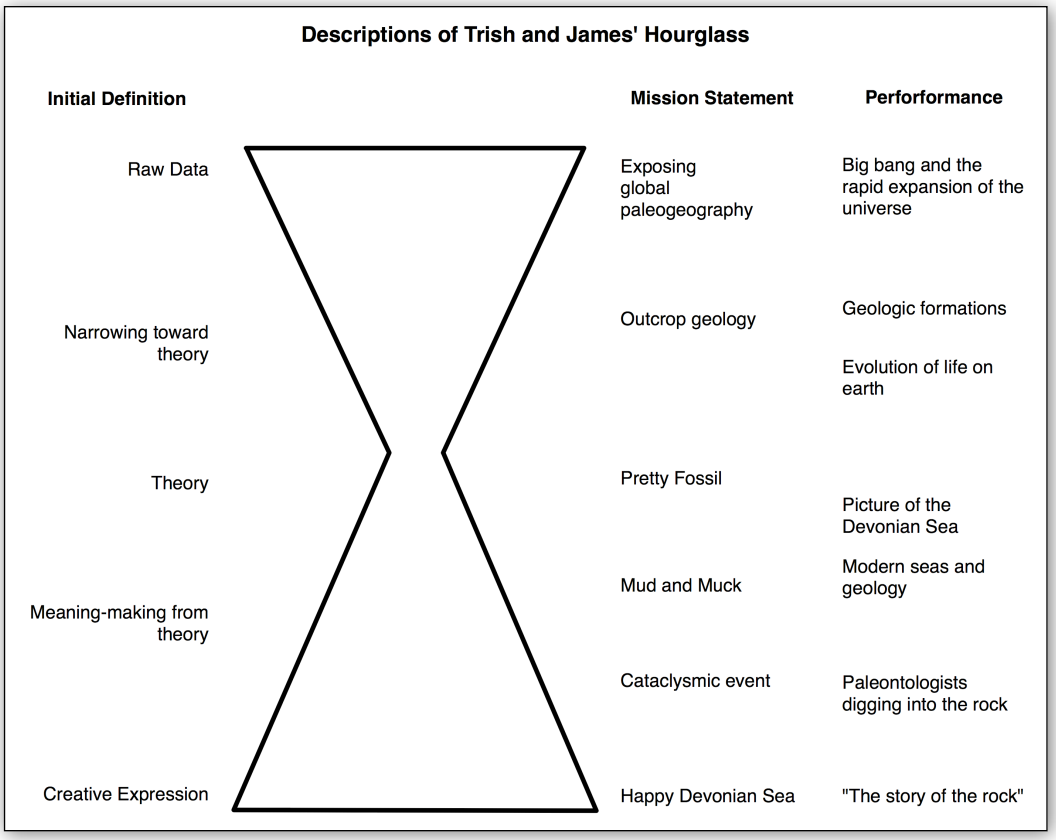


Figure 13: Various meanings of Trish and James' hourglass. While the "Mission Statement" categories were created and written down by the pair, the other categories are my interpretation of their concepts.

arrange the story Trish told, they returned to the hourglass. In different contexts, the metaphor had different uses, though they were all closely connected. In one instance, the hourglass represented the connection between art and science, in another, it represented their mission statement about their performance, and in a third, it represented the story line of their performance. The interpretations of the hourglass were closely connected to one another, and seemed to be iterations of what they meant by the hourglass. Rather than the hourglass being a way for them to illustrate the ideas they were discussing, It was as if they knew that this shape represented their collaboration, and the words they used were different ways of trying to explain the meaning of the hourglass.

Maren and Itai's circle

Like Trish and James' hourglass, Maren and Itai's circle (See Figure 4) was represented by the words they chose, rather than acting as a representation of those words. Itai and Maren came upon the shape of what was similar about their processes before they came up with the words. There was much debate about what words to use, and eventually a conscious decision was made to repeat the same words for both Itai and Maren's explanation of what they do. But the image itself did not change. Much like the hourglass, the shape expressed something in a more clear and more immediate way than the words chosen to explain the shape.

Both the circle and Trish and James' hourglass depicted the pairs' understanding of the relationship between art and science. While these two views were quite different, they are both plausible ways of understanding this relationship. Both arose first without words and then words were added later. Both were

used to help the pairs shape their performance, which yielded very different kinds of performances. While Itai and Maren stressed the similarities in process, Trish and James used the hourglass relationship to create a soundscape to help express the scientific concepts they found important for an audience. It might be noted, the hourglass shape also helped shape the story Trish told.

Metaphor

I realize that the body of literature about metaphor, specifically metaphor in science, well exceeds my current understanding of the literature. While I admit there's a need for much more exploration in the existing literature to fully understand the implications of metaphors found during this study, I will attempt to provide slightly more than a cursory discussion prior to describing my own findings.

Perhaps the best known work on metaphor as a social phenomenon has been done by Lakoff. Lakoff and Johnson (Lakoff, 1993; 1980, 2003) describe metaphor as "understanding and experiencing one kind of thing in terms of the other" (2003, p. 5). Rather than a flowery literary device for poets, metaphor becomes a necessary part of our everyday language and communication. For example, time as money or argument as war. We waste and spend our time, which is a valuable commodity. We win or lose arguments, points are shot down, claims are defensible or indefensible. These metaphors are difficult to see because they are such integral parts of our lives. Most language can be traced to more basic metaphors, of things with which we have direct experience, like good is up, bad is down, and so forth. We can physically and tangibly understand the directions of up and down, and therefore are able to understand good and bad.

For Lakoff and others, metaphor is not a question of language, but rather of thought. "Metaphor then, permeates all levels of our functioning in such way that one might say our ordinary conceptual system is fundamentally metaphorical in nature" (Liakopoulos, 2002, p. 6).

> [Metaphor] is the ontological mapping across conceptual domains, from the source domain of journeys to the target domain of love. The metaphor is not just a matter of language, but of thought and reason. The language is secondary. The mapping is primary, in that it sanctions the use of source domain language and inference patterns for target domain concepts (Lakoff, 1993).

Boyd (1993), speaking specifically of metaphor in science, asserts that metaphor is linguistic in nature, rather than cognitive. "Metaphor is one of the many devices available to the scientific community to accomplish the task of *accommodation of language to the causal structure of the world*" (p. 483, italics in original). Though he speaks of metaphor as a product of language, he also describes scientific theories in which metaphors play a constitutive role, i.e. the theory cannot be explained or otherwise expressed without the use of the metaphor. Some of the examples he provides of these kinds of metaphors include the brain as a computer and stages of development. Boyd also distinguishes between literary and scientific metaphors; however, I did not observe such a distinction in the metaphors used by the pairs.

Metaphors used by the pairs

While several of the pairs relied heavily on visualization, Jim and Lyrae relied almost exclusively on metaphor to communicate with one another, and ultimately, with the audience. Even their final performance can be expressed as

a series of implied metaphors. Jim incorporates anthropomorphized concepts of atoms relaxing and molecules building walls, while Lyrae uses scientific metaphors to express personal experience and emotion.

I noticed that there were two ways a metaphor could be incorporated. The first, the internal metaphor, was introduced by one person to explain a concept to the other. In this case, the metaphor had often been used before. The second case, bridging metaphors, were created by the pairs to help understand the similarities and differences in their work. These were often more interesting to me because they weren't necessarily rehearsed, and I could see the pair's thought process as they tried to build a metaphor that would help them understand one another and express themselves as a pair.

Internal metaphors

Often participants rehearsed a stock of metaphors that were somewhat universal (at least universal within this culture) to help them express something about their work. For example, Itai, in referring to his composite image of the fruit fly as "frankenfly," draws a parallel between the constructed and boxy nature of the fly image and the horror movie character.

It became apparent that Jim often uses metaphors in his writing. He talked about trying to find one's keys as a way of explaining the properties of entropy and he referred to atoms as "cannonball packets." Jim's facility with metaphor is evident in the piece he and Lyrae created. One of the lines, "Crystals, when formed or deformed, relax by developing walls," uses physical architectural metaphors to help express the behavior of crystal molecules. He clearly pre-

ferred to think in metaphor rather than strictly visually. Through his metaphors, however, visuals come to mind easily.

Bridging metaphors

Some of the metaphors created, particularly during Jim and Lyrae's meetings, began with one person's experience and bridged toward something the other person had experienced. It could be said that all metaphors are bridges, but I draw this distinction because of the unique nature of this experience. Bridging metaphors were attempts to directly bridge the work of the artist and scientist. In the following example, Jim has been explaining some of the work he has done on crackling noises

> Jim: ...Roughly speaking, you've got one snap versus lots of snaps...and the idea is you can study this because there are events that span lots of scales, you would study it by studying how small crackles merge into big crackles.
>
> Lyrae: What's the pattern in terms of the small and the large? Because when you're talking about this immediately what I'm hearing is meter, like that there's a natural meter in the world so that if I did scansion like a poet, like if I scanned that poem that it's set and you could visibly see a meter...
>
> J: Okay, so a meter is like some kind of regular pattern that repeats...
>
> L: except that I'm a free verse poet. But we still pay attention to the rhythm, even though they're not regular...
>
> J: fractals are sort of static and crackles are what's happening dynamically, exactly and so I guess I wouldn't' think of it as a meter in time so much as a meter in scale, it's some-

> thing regular on different scales, if that makes sense...when you do a rather crude radical filter to look for scales, they have one noise which means the pattern of loud and soft and high pitched and low pitched is in a sense self similar. The thing I have in my head, which I'm not sure is correct, is if you take Beethoven's symphony, there are quiet bits and loud bits and the loud bits have quiet passages and the quiet bits have loud passages and it's on different scales. All scales are interesting...

While difficult to follow if you weren't involved in the conversation, it's clear at least that the two are working on a way of understanding one of their ideas in terms of the other's.

Maren and Itai had similar exchanges in which Itai compared his videos of flies wing motions to dance, and Maren helped him understand the kind of movements the flies were making in terms of dance.

Completing the bridge

Occasionally, once Jim or Lyrae began a metaphor, the other reciprocated, or completed the bridge. Sometimes the reciprocation would come much later in the conversation, returning the pair to a topic from which they had already moved on. In this instance, Lyrae was trying to make a decision about what line to choose next for their performances. As she was pondering her decision, she bagan to understand a physical concept we discussed earlier.

> Lyrae: Hmm, well...now, that's tough, whether to follow that Iambic, or whether to follow the other thing, the changing mind.
>
> Jim: Mmhmm. It's a branch point here.

> Megan: Yes. It can go either way. It could split and become two different poems. In one reality it could be one, in another reality it could be another.
>
> J: Exactly, exactly! You got it. This is one of the fundamentals of quantum mechanics.
>
> L and M: (laughter)
>
> J: Exactly, exactly. Exactly right.
>
> L: Oh, that's it, okay, I can do both! Ah!

Like visualizations, the metaphors were representations that allowed the pairs to express their ideas and thoughts in a language that could be understood by their partner. But, as Itai suggested, these expressions did not mean the same thing as expressions of artistic or scientific concepts in their native language. They were, in that sense, lies that told the truth. Part of the reason these expressions could not mean the same thing to both pairs is that the participants had very different languages for expression. Like most kinds of translation, the use of visualizations and metaphors did not recreate the exact meaning in a new language, but created a connected meaning that could be shared by the pairs.

CHAPTER 7

BOUNDARY OBJECTS: UNIQUE VISION, SHARED PURPOSE

Chapter 6 described methods of translation the pairs employed to communicate with one another and with the audience, but these methods yielded products, which merit their own discussion. Born out of translations, these objects played a special role in the traversing of boundaries discussed in Chapter 5 and in the formation of a common language by which the pairs could speak to an audience as a unified entity. Each visualization or metaphor, whether created or appropriated for this event, holds a different meaning to its multiple owners, often helping the them create a bridge between ideas and between disciplines and fields. These were 'boundary objects,' which Star and Griesemer (1989) define as, "those scientific objects which both inhabit several intersecting social worlds...and satisfy the informational requirements of each of them" (p. 393). They describe the work of translation that goes on in situations in which multiple actors in a network share a set of resources and a common purpose:

> We are interested in that sort of n-way translation which includes scientific objects. In particular, we are interested in the kinds of translations scientists perform in order to craft objects containing elements which are different in different worlds—objects marginal to those worlds, or what we call boundary objects. In conducting collective work, people coming together from different social worlds frequently have the experience of addressing an object that has a different meaning for each of them. Each social world has partial jurisdiction over the resources represented by that

> object, and mismatches caused by the overlap become problems for negotiation (p. 413).

To understand the nature of a particular boundary object, we must understand what purpose it serves for each possessor. Star and Griesemer discuss the vision each set of stakeholders had for their role in their study, Berkeley's Museum of Vertebrate Zoology. Though each of these groups had a separate goal, whether it was to put forward an ecological theory, to identify and preserve native species, or to maintain a collection that could be seen by the public, these goals stemmed from and fostered a common belief that their work was helping preserve the ecological diversity of California. Boundary objects are not necessarily artifacts, but rather objects that hold some specific meaning in a specific context. Along with the forms used by collectors as they gathered specimens for the museum, Star and Griesemer count the state of California as a boundary object.

Unique visions

In order to understand the boundary objects used in this project, I will first review the vision of each of the key groups that took part in their creation or use. What follows is a description of our individual visions for participating and the situated position in which we found ourselves. It is important to understand each of these positions in order to understand the way boundary objects work in this situation. For our group, the common purpose was the creation and presentation of science based performances. The major actors—the scientists, artists, audience, and I—all operated under the assumption that there was some value in the combination of art and science; however, we each had very different roles and personal visions and goals.

Scientists

Most of the scientists who participated were interested in sharing their work with a broader audience. Itai's doctoral advisor had been interested in the intersection of art and science, and had shared that interest with Itai. Earlier that year, Itai had arranged a party for his advisor that brought together artists and scientists to discuss activities like the Light and Winter Festival. For him, the arts were a way to express scientific concepts. He also had a question, which he asked several times throughout the process and after, about the nature of beauty. So for him this was an intellectual pursuit. Jim, who had been involved in another festival activity several years prior to this (this activity did not end up being presented), also relished the opportunity to learn from artists. As he put it, "It is important to have people listening hard, with different ears."

Part of Trish's job description included planning special events for the Museum of the Earth's Darwin Days celebration, so her interest was also in the arts as a form of scientific outreach. Likewise, Holly's job was tied to Cornell's extension program, which has a mission to share scientific knowledge with the public, so dissemination of information was important to her, though it is worth noting that Holly's is a special case because her work was not solely communicating science, but also communicating risk.

Artists

Maren and James were familiar with the Festival and were interested in the opportunity to perform. Lyrae's forthcoming book of poetry, *Open Interval*, incorporated mathematic and astronomical themes, and she had been so inspired by this work that she was interested in exploring more scientific themes.

Spencer, a graduate student who was nearing completion of his PhD, had composed works based on the lives of scientists in the past, and was interested in trying something new. His interest was that of an artist, but at the same time, as a scholar, he hoped to write a paper about his participation.

Just as the scientists viewed this opportunity through the lens of their own work, so did the artists. For them, it was an opportunity to perform; it was a subject that inspired. Because these artists worked individually, their connection to the project seemed more personal than the scientists, who, while they worked on this project alone, were part of a network that shared the responsibility for the knowledge they produced or disseminated.

The audience

While the role of the audience in the use of boundary objects is a bit unclear, it is worth examining their possible interpretations of such objects. As I mentioned above, it would be impossible to say with certainty what each audience member's vision of this project was, and more impossible to make the claim that they shared one vision. We can, however, make a few assumptions based on their presence at this performance, and we can know still more through survey and focus group data. A full analysis of that data is outside the scope of this study; however, preliminary investigation shows that the audience was very familiar with the Festival, and that either they were there to see someone they knew, or they were attending several events that day of which this performance was one.

Audiences came expecting to participate in a kind the ritual in which they experience an event together. This ritual form of communication is not an at-

tempt to transmit messages, rather, it is a way in which a community comes together to express a shared belief (Carey, 1989). In this case, the shared belief may have been one of the power or importance of art or science, or it may have stemmed from a belief that knowledge should be celebrated. Though this was, in many ways, a ritual, I believe audiences still hoped to learn from the performance. Circumstantially, some might have expected to participate in an event because they were given plastic slide whistles at the beginning of the performance. Some said they expected this performance to be a lecture, in which I spoke about art and science, and were pleased it wasn't. One audience member wished it had been.

The researcher and producer

I do not intend to discuss the role of the creators or producers of the festival, since they are not central to this study; however I had a large stake in the event as both a researcher and a producer. My vision for the performance often worked in concert with, and sometimes in contrast to, my vision for the study. As I discussed in Chapter 3, I was balancing the need to present a good show with the need to understand the creative process between my subjects. My vision was to create an engaging performance, and to document and learn from the process as well as the audience response to the project.

From these different standpoints, we built a united purpose not only to create and observe a performance, but to further explore the intersection of art and science as it related to our individual visions. It was out of these individual visions we fashioned the boundary objects we used.

Appropriated, existing, and manufactured boundary objects

I found that there were three main categories into which boundary objects for this project fell. The first, existing boundary objects, were part of the existing body of work of either the artist or the scientist, and were brought into the project for one reason or another. For example, Itai's movies of fruit flies, or the graphic conventions of Trish's geological illustrations. The pairs also created boundary objects, like the hourglass drawing Trish and James created to help them understand the relationship between art and science. Finally, there are boundary objects which were appropriated; which had specific meaning in their own context but were used by the pairs to create new meaning for both the scientists and the artists. Jim and Lyrae's excerpts from their published works were used to make an object that did not mean to either of them what it meant to them in its original context. These appropriated objects were new creations, made with fragments of existing work.

Existing objects

Existing boundary objects are artifacts or abstractions brought with participants into the project. Itai's flies are an interesting example, because there are several ways to interpret what is or is not a boundary object. One could say the flies themselves are boundary objects, but it seems to me that there is no common understanding of the flies within the context of the project. To Maren they are small and annoying, and invade her fruit, but to Itai, they are the embodiment of several scientific concepts; they are laboratory subjects; they are engineers. It was not until we looked at the close up image of the fly and then the movies of the fly that both Maren and Itai shared the flies. The movement of the fly became inspiration for Maren's dance, and it still provided

information for Itai that allowed him to perform calculations and learn about the physics of the fly's wings. The overlapping nature of Maren and Itai's work—their shared sense of observation, interpretation, and sharing—helped them to find a common way to work with the video, but the result was drastically different for each of them.

Trish had a set of graphic conventions to which she adhered when making drawings of the layers of rock at the waterfalls. These conventions were universal and communicated specific properties of the geologic formation of the rock to other paleontologists and geologists. They were also a teaching tool that allowed her to teach first James, and later the audience, about the way sediment falls and forms different kinds of rocks. This boundary object was a roadmap in one world and a literal visual aid in another. James found this so compelling that he asked her to share the same graphic conventions with an audience.

Built objects

As the pairs worked together, they created boundary objects, but the first built object was the cultural probe itself. I created the probe with several goals in mind, but once it was given to the pairs, they made something entirely different. In some cases, pieces of the probe became part of the performance. Most built objects were created during the execution of the cultural probe. This is where Trish and James created their hourglass, which took on several different meanings throughout the course of the project, though the shape resonated with both of them, and each time one of them articulated an interpretation, the other agreed. Theit individual interpretations were fluid and held different meanings within the agreed upon interpretations.

Similarly, Itai and Maren created the circle diagram to help them understand the similarities in their work. The image did not exist in either of their minds prior to the second meeting, in which they drew the shape and simultaneously began to walk and think in terms of the shape. Though they created the image together, for each of them, it expressed something unique. For Maren, it was an expression of a creative process of choreography, it was a shape that could be replicated with the body, which is why the two of them began to move in a circle. For Itai, it was an expression of the social process of science, at least the process he went through in his own work. It represented the cyclical nature of science, and the fact that the endeavor is without end.

Appropriated objects

In some sense all of these boundary objects are appropriated from other contexts, and some of them change meaning for their owners, but here I am referring to objects that had a specific meaning to one of the participants but was used by that participant for an entirely different reason, as the individual lines Lyrae and Jim Because they each used single lines from their published work, the lines became decontextualized. Jim's first line, "nature is very complicated" was the first line of his dissertation, and retained the meaning it had for him; however, when decontextualized and placed next to Lyrae's "I cannot tell the dipper from Orion," Jim's line took on a new meaning for him: one that was mingled with the context of his dissertation, but also, one that was part of a new whole, belonging in a new context. Similarly, when Lyrae recognized that Jim's line "What happens then, when atoms change their mind?" was in iambic pentameter, she decided to choose a line from one of her poems that was also in iambic pentameter. In this case, the meter itself became the new context for

her line, rather than the meaning. Once again, her own work was decontextualized and recontextualized in such a way that it had a different meaning for her in their co-created piece than it did in her own poem.

Understanding the boundary objects

To understand the importance of the boundary objects in this process, it is important to understand the context of Star and Griesemer's work on boundary objects. Their paper was a response to Latour, Callon, and Law's development of Actor Network Theory (ANT) (Callon, 1999; Fujimura, 1992; Latour, 1988; Latour, Sheridan, & Law, 1988). While Star and Griesemer adopt some of the ideas from ANT, their approach differs in that they take an ecological view of Latour et al.'s networks. By doing this, they can examine "an indeterminate coherent set of translations" (p. 390).

> Our approach thus differs from the Callon-Latour-Law model of translations and *intéressement* in several ways. First, their model can be seen as a kind of 'funneling'—reframing or mediating the concerns of several actors into a narrower passage point. The story in this case is necessarily told from the point of view of one passage point—usually the manager, entrepreneur, or scientist. The analysis we propose here still contains a managerial bias, in that the stories of the museum director and sponsor are much more fully fleshed out than those of the amateur collectors or other players. But it is a many-to-many mapping, where several obligatory points of passage are negotiated with several kinds of allies, including manager-to-manager types. (p. 390. See also Figure 14)

The strength of Star and Griesemer's model, especially in this context, is that they do not give preference to a specific interpretation or use for boundary objects. A network approach like Latour, Law, and Callon's considers the ways in which scientists recruit allies and establish facts, while boundary objects do not serve to align different factions around a "fact" as it is created, but rather, allow collaboration across diverse social worlds (Fujimura, 1992). Fujimura goes so far as to say that the concept of boundary objects are disadvantageous when trying to build allies to establish fact.

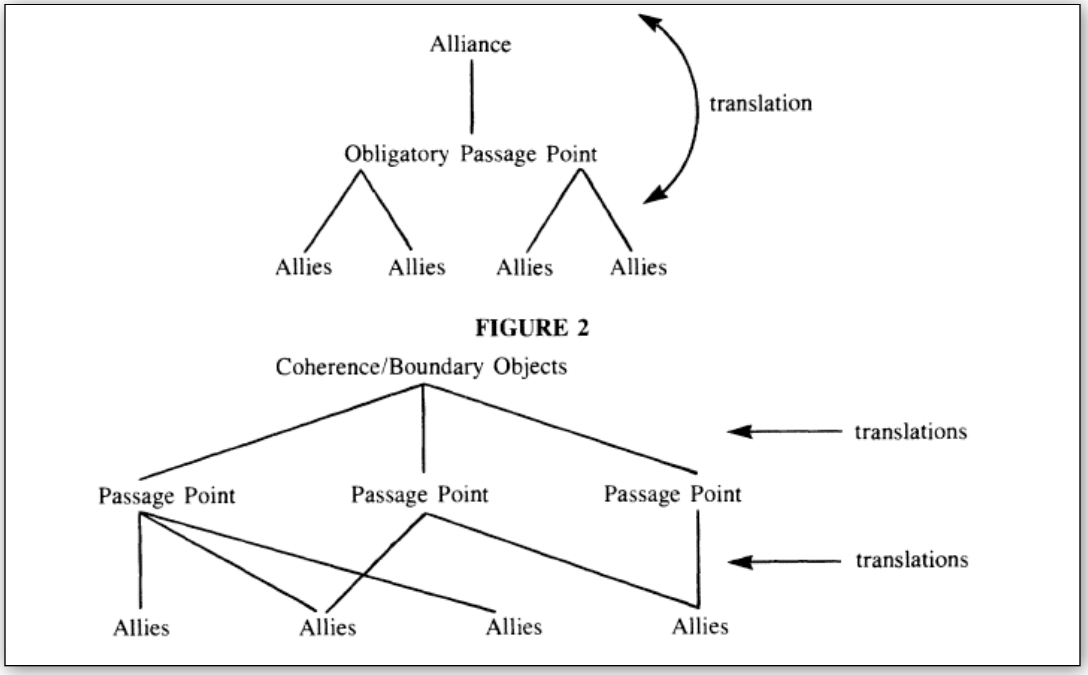


Figure 14: Obligatory passage points in the ANT and Boundary Object models (Star & Griesemer, 1989, p. 390)

By adopting an ecological view, rather than a network view, Star and Griesemer were able to examine the many ways in which scientific information could be used and understood. This distinction could be very important in considering the nature of science performances. Performance is often left open for interpretation by audiences, and audiences often come to performances expecting to make judgement about what they will see. A performance that presents

only one passage point might be stifling to audiences, whereas the multiple passage points available in a boundary object model creates space for audiences to bring their perspective and experience into the interpretive process. This space could mean the difference between a deficit model of science communication and an engagement model. Science communications experts recognize the need for engagement, but what engagement in science means is not yet clear. Perhaps multiple passage points are a sign that the public is engaged in understanding the science in different ways, making room for discussion.

CHAPTER 8

CONCLUSION

My aim for this research project was twofold: I wanted to learn something about the potential benefits of artist/scientist collaboration to artists, scientists, and audiences. More broadly, I wanted to use this information to help shape the beginnings of a theory about the relationship between art and science. This project is a first step toward a career-long exploration of art and science as forms of communication and knowledge types, and it has begun to shape the course of that exploration. Because the questions began so broadly, I will now attempt to redraw these questions based on the findings.

Inspirational and foundational experiences

My first question, regarding the processes and effects of artist/scientist collaboration, can be addressed by examining the role the cultural probe played in shaping an experience. The evidence suggests that the cultural probe had a strong impact on the creation of the performances, and in some cases, it had an effect on the participants themselves. The question, then, is how did the probe shape the experience? What can we learn about creating positive collaborative experiences for artists and scientists?

Before I begin discussing the probe in earnest, it is important to return once again to my role in the process. As the facilitator and creator of the probe, I created a particular environment for their experience. The questions in the probe prompted the participants to engage in a discussion about the nature of art and science, opening the way for the boundary work that was done. My role in shaping these questions indicates I was interested in their understand-

ing of the boundaries, and looking for ways to challenge boundaries before the participants even came in the room.

Dewey (1934) draws a distinction between experience, which is an ongoing state, and *an* experience, when that which is experienced "runs its course to fulfillment" (p. 36). Experiences have an aesthetic quality, without which there can be no sense of unity or fulfillment. I suggest that by beginning with the probe and culminating with a performance, most of the pairs engaged in an experience by Dewey's definition. The probe shaped each pairs' experience, which consisted of boundary work, translation, and the creation or discovery of boundary objects (aside from Holly and Spencer, who had an anomalous trajectory). Trish and James were unable to carry out their plan to go fossil hunting together, which left Trish with a feeling of incompleteness. While she enjoyed the process and was proud of the product, she wanted to experience, as she said, a role reversal of some kind. She felt their abandoned field trip would have shaped the project differently, and might have given here that opportunity. The other three scientists seemed to feel a sense of wholeness in the project. These scientists are actively seeking opportunities to work with artists again.

Not only was the entire project an experience for the pairs, the probe alone created a complete experience. The look and feel of the envelopes and prompt cards, the ritual of opening a new envelope for each prompt, and the sense of closure when the pair had identified a mission statement, put most of them at ease and gave the feeling that they were ready to begin to create a piece. After completing the probe, Jim exclaimed, "I'm much less terrified now." Later, he explained the terror he felt came from disbelief that he and Ly-

rae could actually create something in just six hours. If he had not felt a sense of completion of the probe, I doubt he would have felt such relief. I do not believe the pairs would have been able to create the kind of performances they did without the probes, and I wonder if the project would have had the sense of fulfillment Dewey talks about.

The experience created by the probes was inspirational for some and foundational for others. For Trish and James as well as Holly and Spencer, the probe was inspirational. Ideas generated during the probe helped form the basis for what they would do, but ultimately, the subject matter existed prior to their experience with the probe, and the knowledge they ultimately shared with the audience would likely exist regardless of the interaction.

I do not claim there is a clear dichotomy between the foundational and inspirational experiences, but rather, a continuum of experiences that range from inspirational to foundational, and between expressions of scientific concepts using the arts, and expressions of something about the nature of science and art. Maren and Itai, for example, straddle this continuum. Itai spent a bit of time explaining his work with fruit flies, and Maren did some interpretation of the fruit fly videos themselves, but the crux of their performance centered on the similarities in process.

This inspirational interpretation of the cultural probe seems to be tailored more toward a specific scientific topic. Holly's work with the Institute for Invasive Species and Trish's work with the Museum of the Earth may have demanded that the two of them present more specific information than Itai or Jim. In each case, there was a specific subject or specific information they wanted to get across to their audience. In addition, the artists working with Holly and Trish

both seemed to understand their role as one in which they had a specific message to present, while Jim and Itai were open to expressing something else.

Foundational experiences with the probes were exemplified in Lyrae and Jim's constructed conversation, but were also evident in Maren and Itai's discussion of process. These foundational experiences allowed the pairs a wider range of possibilities, in part because they did not have specific expectations of what they would present, and in part because they learned something from the probe and chose to express what they learned. The more foundational experience also included artists that expressed the desire for the public to understand something new about their work. Both Lyrae and Maren expressed a desire for a "Public Understanding of" their respective disciplines. This may have pushed these pairs to explore outside their comfort zone, or even outside what they thought they might want to present to an audience.

Boundary work

In subsequent conversations with Jim, he expressed his interest in using a project like this to shape his own thinking on theoretical concepts. This suggests to me at least a potential for foundational experiences like Jim's to cause a shift in participants' perceptions of boundaries. Similarly, Itai appeared to question the boundaries between art and science. Future research should address whether these foundational experiences can be used to redefine existing boundaries between disciplines, and what effect these boundary shifts have on the scientific or artistic processes.

The boundary work in which the pairs were engaged suggests it would be beneficial to ask some questions about the nature of the boundaries them-

selves. While the pairs were engaged in charting boundaries, many of these boundaries had already been established and discussed by the likes of Snow, Popper, and Gieryn. The formation of boundary objects may have softened the rigidity of the existing boundaries. Does this kind of boundary deconstruction detract from professionalism? For quite some time, science has enjoyed a quite privileged and powerful role that art simply has not been able to attain. Though this may not have been the way Snow perceived the status quo in 1959, it is certainly something for which he advocated. If future work indicates a significant restructuring of boundaries even in an individual scientist's perception, it will be important to look into the ramifications.

It will also be important to engage in future research regarding the difficulty—or perceived difficulty—of crossing boundaries. Foucault suggests that the formation and promotion of the disciplines was a way of securing power (1979), an idea that coincides with Gieryn's description of professionalization. If the boundary work the pairs engaged in reified the power structures put in place by the formation of disciplines and professionalization, did the translation and subsequent boundary objects break these structures, or in any way change the nature of the boundaries and disciplines?

Visualization and metaphor

Both visualizations and metaphors helped the pairs express thoughts and ideas that seemed more immediate than the language in which they would ultimately be expressed. The visual models Trish and James and Maren and Itai created came before the words they used to describe the visualization, because there were not yet existing descriptions of what they wished to express. First, the circle or the hourglass resonated with both members of a pair, then

the words to describe the circle or hourglass were negotiated. The pairs shared an immediate emotional response to the images, allowing them to use the shape, rather than the words, to guide their creative process.

Though there is disagreement among scholars as to whether metaphors are linguistic or cognitive, many agree that they can be constitutive, or necessary, to the expression of an idea or concept. Within the sciences metaphor is often used for creative problem solving, and metaphor is essential to artistic expression. The creation of metaphors, like the creation of visualizations, came from a need to communicate without a common language, which forced the pairs to to be creative, and to draw on their imaginations to communicate.

Because they didn't have a common language, they began to use their imaginations to develop visualizations and metaphors to communicate with one another. Imagination became necessary to their process. Perhaps this is one of the greatest benefits of artist/scientist collaborations: the removal of a standard language necessarily makes way for the creation of new languages, or, as Itai might suggest, new lies to tell the truth.

Boundary objects

The fact that each group came to find at least one boundary object they could use to bridge their worlds, and that the object was often quite different and symbolized very different things for each pair, suggests to me that these objects are not unique. That is to say, these objects are indicative of a shared set of ideals, rules, or principles. That these objects could be used to communicate with an audience indicates that collaborations such as these can be used as a method of engaging the public.

Though Star and Griesemer consider boundary objects a way of translating information, I think what makes them boundary objects is that they allowed the pairs to move beyond translation. Through these objects, two distinct perspectives were able to create something that would communicate with an outside party: the audience. The audience was presented with these boundary objects during performances, and while they had still another perspective from which to view the objects, their perspective incorporated both the artists' and scientists' interpretations, but also interpretations made by each pair together. While they helped the artists and scientists understand one another, they also provided a common language by which the pairs could communicate ideas created together to an audience. In this way, the boundary objects helped them formulate a common language rather than a translation between two languages. The difference is one of being able to know and to do. Boundary objects allow their owners to work together, though the object remains situated differently in each world.

The video of Itai's flies was used as a way for the pair to communicate with the audience when it became a symbol for both Maren and Itai's observations about the world. Their cycle of observe, interpret, and share needed a strong, physical example to share their interpretations with the audience. In their case, the observation and interpretation was about process, not necessarily about the flies. To Itai, the flies represented the potential knowledge humans could gain by understanding their movement, and they represented a large part of his career, one in which he had made an investment of time and resources for a number of years. For Maren, they did not have the same baggage. She was trying to interpret them as a way of moving, as a form of expression of not only the work Itai was doing, but of the process they went

through together. For her, the flies were an expression of form, of rhythm, and of movement. While Itai recognized the potential for this kind of interpretation of his fly videos, he could not explain that potential or express it in the way Maren did when she chose two different pieces of music and choreographed the two dances.

The first piece of music and choreography drew upon the overall motion of the fly as it rose from the floor. The second, an up-tempo song, echoed the more rapid movement of the wings as the fly rose from the floor. When she told Itai about these two interpretations, he said that they did, in fact, measure these two different qualities during their research. Though they had different uses for the fly videos and explained them separately to the audience Itai and Maren used the fly videos to express their separate interpretations, but their observations had been more similar than they initially realized.

Perhaps in the future special attention can be paid to creating objects that public also has a vested interest in and of which they have a specific understanding. Perhaps this is what happens when scientific concepts are related to subjects with which audiences already have a working body of knowledge. For example, there are often short programs or books that describe the "science of" something that is commonly understood, like baseball or Star Trek or Harry Potter.

Future Research

This project opened the doors for future explorations of the relationship between art and science. Future studies could investigate what impact processes like this have on the participants. For example, the similarities in proc-

ess Maren and Itai discovered may have an impact on their work in their respective fields. How will this change them professionally? Jim expressed the desire to use experiences like this to further his research. Perhaps for him, Lehrer's (2007) idea of an artist in residence in labs or other research facilities has the potential to be a reality. What would be produced by these laboratories? Will it be art, science, or both?

Beyond the rewards of collaboration for artists and scientists, there is much work to be done on how such collaborations affect the public. We do not yet have a clear picture of what engagement means, or what effective engagement with the public looks like. Evaluation of public performances or demonstrations of art and science in the context of science communication will help us determine what, if any, unique benefits there are to presenting art/science collaborations to the public.

Finally, a comprehensive theory of the relationship between art and science is not yet within the reach of the handful of scholars who are interested in the subject. The two research paths outlined above can serve as a step toward building a theory of art and science.

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