The PIE Institute Project

Final Evaluation Report

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> *[PIE is about] giving people experiences so that they can practice observing, having a hypothesis about what is going to happen, seeing what is happening, and then making changes based on all that… We believe that having a kinesthetic experience with phenomenon is important…*[1]
>
> Kristen Murray, Interim Director of Learning Technologies Center, Science Museum of Minnesota

INTRODUCTION

The Playful Invention and Exploration (PIE) Institute project was funded in 2005 by the National Science Foundation (NSF). Building from a previous NSF grant, the PIE Institute project sought to:

> *…continue the work of the PIE Network by continuing to create playful and inventive educational activities using science, art and technology, and by sharing PIE ideas with a larger audience of educators in museums and other kinds of informal learning environments.*[2]

Mike Petrich and Karen Wilkinson at the Exploratorium, working with partner museum educators from the Science Museum of Minnesota, Fort Worth Museum of Science and History, and Explora Science Center and Children's Museum of Albuquerque, set about to refine PIE activities created in the previous round of funding, to create new PIE activities, to implement PIE activities in new settings and contexts, and to broaden the group of museums who were engaged in PIE learning and work at their own institutions. In addition, the PIE Institute project was interested in documenting, in rich and inventive ways, the nature of their work in order to make it available to a broader audience.

This Report

For the past three years, Inverness Research[3] has served as the external evaluator for the PIE project. Our evaluation efforts have included extensive observation and documentation of PIE project activities; ongoing in-depth interviews and discussions with project leaders and participants; a survey of PIE participants; and a review of the project's website.

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[1] Quotes have been lightly edited for clarity.
[2] From the PIE website: http://www.exploratorium.edu/pie.
[3] Inverness Research is a private education research and evaluation firm. For more information, see http://www.inverness-research.org.

Overall, we have found the PIE work to be innovative, highly engaging and very meaningful to participants. It has also resulted in significant broader contributions to the field of informal science education institutions. In this report, we will summarize the findings from our study of PIE, beginning with a brief description of the project and its activities, an analysis of the PIE philosophy and approach to teaching and learning, and an illumination of the key elements or defining characteristics of the PIE approach. We follow with a discussion of the contributions the PIE project has made to its participants: personally and professionally, to their programs, and to their institutions. We will also discuss the important contributions the PIE project has made to the field of informal science education institutions. The third major section is a discussion of some of the challenges the project has faced, and opportunities going forward.

PIE DESCRIPTION AND PORTRAYAL

PIE is a unique project that combines elements of inquiry-based science teaching, art and creativity, technology, and design challenges in powerful ways. As stated in a recent proposal submitted by the Exploratorium to the National Science Foundation, "The PIE concept of playful and inventive learning is inspired by the research of the MIT Media Lab, by the explorations of Reggio Emilia schools, and by the creative ferment of artists' studios, scientists' laboratories, and tinkerers' garages."

We begin our report with a description of the PIE project and its main activities, followed by an in-depth exploration of the PIE philosophy and approach to teaching and learning.

The PIE Institute Project and Activities

The PIE Institute focused on providing in-depth experiences for museum professionals around PIE activities, which center on the use of technology and design challenges to create powerful learning experiences. PIE leaders wanted to develop the leadership capacity of informal science educators, particularly those from partner museums, to engage their own local participants in activities, as well as the capacity of educators to provide PIE professional development experiences for other informal science educators. PIE leaders were also interested in refining the PIE activities that had been developed during the PIE network grant, and in adding new activities to the project's repertoire.

The core activity of the PIE Institute project is the "atelier," an in-depth, one-week institute in which a variety of participants from national and international informal science education institutions participate. The term atelier means "a workshop; or a studio for an artist or designer." The ateliers have been organized around different themes – such as kinetic contraptions, art machines, and sensor gardens – engaging participants in creative, immersive inquiry and construction around specific design challenges. They also include work with

"crickets."[4] Local artists also actively participate in these workshops, demonstrating their work to participants, and engaging in PIE activities alongside participants.

Two examples of the types of PIE activities included in the ateliers illustrate the nature of the work that is done. One activity focuses on scratch film/sound automata and another focuses on creating machines that illustrate a chain reaction. In the scratch film/sound automata activity, participants prepare strips of film leader by scratching them or adding paint to them; these are spliced together to make a collective film. Then participants each design and build a machine that will make sound that involves a motor which is attached to a cricket. The cricket is programmed to react to light – either turning on or off when light hits the sensor attached to each person's machine. The foundation or building-block activity that participants engage in before this one is the creation of cardboard automata where participants explore cams and levers. The building of the sound machines and initial activities usually takes two days. At the end of this activity, the machines are placed on the stage and the film is run. The light from the film triggers the sound machines to go on and off, creating an improvised soundtrack for the film.

Another example is a chain reaction activity. In this activity, squares are blocked off or interconnecting tables are set up, and participants are paired up and choose a square or table. Each group must build a chain reaction in their space that connects up with the spaces on either side of theirs. In the end, the giant chain reaction is set off. Sometimes the constraint for this is that participants include at least one circuit in their individual chain reactions; other times, the design challenge has involved the layering of a metaphor – for example, creating machines that demonstrated love. The foundation activity participants do prior to this involves three centers of activities that allow participants to explore inputs, outputs and resistance sensors with the cricket.

In all, seven institutes or ateliers were offered: three at the Exploratorium, two at the Science Museum of Minnesota, and one each at the Fort Worth Museum of History and Science and at Explora!. PIE leaders also hosted a half-day workshop on Light Play during the 2008 ASTC conference, and hosted an innovative and wildly popular PIE tinkering studio in the exhibit hall. In addition to the institutes, the PIE work encompassed work with visitors on the floor and in the Learning Studio at the Exploratorium. Work at the Exploratorium with visitors included workshops on marble machines, chain reactions, "digital bling," light play, wind, and "squeezeable circuits." PIE leaders also participated in events such as the Fort Worth Mindfest and Maker Faire.[5] They also consulted with museum professionals across the country and internationally who were interested in incorporating more PIE-based activities into their institutions. In addition, the project created an extensive website[6] with photos of ateliers and workshops, activity ideas, resources, PIE network member contact information, and detailed descriptions of the ateliers.

[4] Crickets are small, programmable devices developed by the Lifelong Kindergarten group at the Massachusetts Institute of Technology Media Lab. The Playful Invention Company (PICO) sells PicoCricket kits (see http://www.picocricket.com).

[5] Fort Worth has held several annual "Mindfests" which are large events at the museum designed to provide PIE-inspired activities for thousands of visitors in a single day. Maker Faire, sponsored by Make Magazine and Craft Magazine, is a gathering of artists and tinkerers that "celebrates things people create themselves."

[6] http://www.exploratorium.edu/pie

Thus, the project was designed to foster PIE leaders' continual refinement of their skills in developing and sharing activities with other informal science educators; to develop additional leaders in the informal science education community who could facilitate PIE professional development experiences for other educators; and to develop a broader community of ISE educators skilled at providing meaningful PIE experiences to their visitors.

Overall, 150 educators from informal science education institutions participated in the seven ateliers and workshops. Working directly with visitors at the Exploratorium reached an estimated 400 people. Extrapolating from our survey data, we conservatively estimate that easily more than a hundred thousand visitors have participated in programming in institutions across the country and internationally that are based on or inspired by PIE.[7]

The PIE Approach to Teaching and Learning

The approach to teaching and learning in PIE activities is unique. The approach centers on the use of technology and design challenges to create powerful learning experiences for use in informal education settings. The domain in which they are working involves invention and construction, providing people the opportunity to envision something and then build it. It involves inquiry in the context of design, where people try things, refine them, and try them again, moving back and forth repeatedly between the envisioning and the construction. Thus, participants engage in construction with a functional intent and a feedback loop. As Mike Petrich explained:

> *I am building something so that it tells me what implications my redesign has had… I find out how my thinking is working through what my construction tells me, the feedback that it gives me… And that is why the act of construction is important.*

This domain also involves integrating art, science and technology – more old-fashioned technologies of construction, tinkering and building, as well as new digital technologies, called crickets. One PIE leader described the combination of art, science and technology:

> *…the blend of art and science and design is also central to PIE… and we are looking for inspiration in all of those places. Educators are drawing on inspiration to create a new PIE activity, and participants are looking for inspiration to design something to meet the challenge that is given them…. technology is important in extending these activities and making these activities more special. And that technology could be a digital technology, like a cricket, or another kind of simpler technology – one you can buy or one that is invented by the educator to make that activity possible and richer.*

PIE brings these elements together in new and creative ways. As one participant noted:

> *…in my world, it was a separate world between art and science. For me, personally PIE has closed a gap. The people that are really interested in the science are being given the*

[7] In the spring of 2007, we administered a survey to all museum educators who had participated in PIE ateliers up to that time. The online survey was distributed to 51 PIE atelier participants; 22 participants completed and returned surveys, a return rate of 43%. The survey data represents roughly 34% of the final number of atelier participants.

> *opportunity in a comfortable way of experimenting and making art without being intimidated by it. Because I really feel that people are just as intimidated by art as they are science. I feel like the two are equal. PIE really is kind of bridge for those two things.*

Another important feature of the PIE approach is that participants engage in constructing things that are personally meaningful to them. Several PIE participants describe the PIE philosophy with regard to personal constructions:

> *I think PIE is really about digging deep and getting back to the idea that we need to be working with our hands, with materials, in ways that are open ended and that are guided by our curiosity and by questioning and observations.*

> *…there is an open-endedness to it. There is a common goal or a task that might be at hand but there are countless ways of getting to that end and it allows for people to express their curiosities or draw from their personal experiences and backgrounds in reaching that goal.*

The PIE approach is also heavy on self-challenge, and of design under constraint. Participants come up with their own challenges within some broad framing (for example, building something that will make a noise when light is shined on a sensor; creating things that can have a conversation or tell a story; making a marble machine where the ball moves very slowly). The challenges posed are not completely open-ended and there are enough materials present so that people have options, but not so many that they are overwhelmed. Also, there is no competition involved except what participants impose on the process themselves. There is facilitation by knowledgeable people who guide and help people when they get stuck. The combination of environment, materials, and facilitation helps people choose challenges at the appropriate level. The ultimate aim is for people to be empowered – to engage with materials, create something with them, and learn from those materials and experience the process of creation. As people succeed, they continually expand their zone of development so they have greater capacity and greater confidence to create things.

Core PIE activities are based in content areas that naturally invite exploration – light and shadow; wind; chain reactions; sound; marble and ball runs. The depth of these content areas allows participants to go as deep as they want in exploring that phenomenon.

Learning Goals of PIE

There is a great deal of learning that occurs for participants in PIE activities, but it is not school-like, conventional, science content learning. Rather, the focus of learning in PIE activities has more to do with process skills and phenomenological kinds of learning – exploring materials and phenomena and building fluency in those areas. Building fluency with materials, with tools, with the design process, with the way things work are all important underlying notions of the PIE work. As Mike Petrich said:

> *We are trying to provide opportunities for people to become more fluent in terms of how to use materials and tools to suit their needs to answer a question or to create something that will perform or behave in a certain way or to demonstrate their thinking…*

PIE leaders have been explicit in focusing on phenomenological and experiential kinds of learning rather than on specific science content principles and facts. They have deliberately avoided duplicating the kinds of science learning experiences that schools provide. Participants in PIE activities understand, appreciate, and value this type of learning. Participants we interviewed were very articulate in expressing PIE learning goals:

> *My interpretation of PIE is that it is very process driven… it is very much focused on the experience of individuals that are participating in the activities. And that experience is the process of working with various phenomena or being creative… people run into problems they have to solve, through trial and error, to work through various iterations of whatever it is that they might be creating or experimenting with. That is the focus of their activities and yet the content is underlying it, and so any science content that is gleaned out of these activities or creative projects comes as secondary to the actual experience…*

> *I would say that the number one thing that people learn is how to go about solving problems, how to test things out, how to come up with a hypothesis as to why something may or may not be working, recognize where problems are occurring and come up with creative solutions for those problems. That is a skill that is valuable in most aspects of life, but it is a skill that they don't necessarily get a lot of time to practice…*

> *It is providing people with an experience where they can start to relate and connect things. When you are giving a kid a motor and you are making a scribble machine, and they are learning about the construction and the engineering, they might not remember what their drawing was, but they are going to remember their construction of it.*

Thus, the activities involve "constructionism – the construction of knowledge in the context of building personally meaningful artifacts." By trying to design and make something, one learns things. What people gain from participating in this experience is not so much content-specific as it is about empowerment – they gain confidence in knowing they can make something, as well as some programming and construction skills. As one PIE leader said:

> *Seeing how materials work and respond to one another builds vocabulary and their facility in exploration. It isn't something you can test for. Increasing or accentuating a way of thinking or a way of processing gives people the tools to truly understand things when they are later presented to them in a more traditional context, with labels and theorems. Having the sort of visceral understanding of how things work is crucial.*

PIE learning is also very much learning through play. As one participant noted:

> *… the pre-eminence of play as part of learning is something that disappears after early childhood and I think PIE puts that back to the forefront and lets you giggle and have fun*

> *and play there… and then it maps on this really deep pedagogy… of questioning, investigation, making predictions and hypotheses and working with material.*

The activities of the ateliers frequently push participants to the brink of frustration – to a level of being stuck where there is an opportunity for learning to happen. One atelier participant described the beauty of being challenged by PIE activities:

> *If you can pull something off, even get close, you feel like you own it. It is yours; you are not imitating somebody else. That frustration is part of PIE. Failure is the fist step to success. Over the course of my life, I have been conditioned to dislike failure and I haven't really learned how to deal with it well. But PIE is good at that, making you feel like that is when the good things happen.*

One participant in the Light Play workshop at ASTC talked about how much more work, and how much richer, the learning experience in PIE is.

> *When you do an activity like this, you have so much control over your own learning experience. It is a lot of work, a lot more work than just sitting there passively taking notes. I wasn't sure I wanted to work that hard today. But then while I was doing it, I noticed I was totally having a flow experience of learning, that ideal learning experience.*

The PIE activities we have observed have frequently led to "flow" learning experiences. Csikzentmihalyi and Hermanson[8] have characterized activities that produce flow as having clear goals and appropriate rules, immediate and unambiguous feedback, where one knows if one is doing well or not, and where the challenges of the activity match the skills of the participant. When all of these things happen, participants become wholly involved in the activity. "In a flow state, a person is unaware of fatigue and the passing of time – hours pass by in what seems like minutes. This depth of involvement is enjoyable and intrinsically rewarding. Flow activities lead to personal growth because in order to sustain the flow state, skills must increase along with the increased challenges…. Flow activities provide a sense of discovery – we discover things about ourselves as well as the environment." Almost all of the PIE experiences we have observed have been "flow" experiences for participants – they are fully engaged, deeply involved, and find the experiences highly rewarding.

Key Features of PIE

In this section, we discuss some of the key features that underlie the PIE approach, the interplay of which creates meaningful experiences. PIE involves a critical intersection of materials, environment or space, and facilitation around real science phenomena.

[8] Csikszentmihalyi, Mihaly, and Kim Hermanson. *Intrinsic Motivation in Museums: What Makes Visitors Want to Learn?* Museum News. May/June 1995, pages 35-37 and 59-61.

Real Science Phenomena

First and foremost, real science phenomena are at the heart of every exploration. Light, color, sound, wind, motion, forces – these rich content areas foster the generation of questions, invite exploration, and lead to aesthetically interesting experiences for project leaders and participants.

Materials

Providing opportunities for participants to "mess about with materials" is a very important piece of the PIE work. As one PIE leader said:

> *One of the core ideas of the PIE approach is creating environments for people to learn by working with materials, whether it is making things, experimenting with materials, designing something, [or] playing around. The materials are core, and the learner focus here – hands-on, open-ended – is important.*

The materials to be made available to participants depend on the activity, but include simple, readily-available, inexpensive items, such as dowels, wood scraps, fabric, foam board, wire, mylar, strawberry baskets, and PVC pipe. Using materials, building something with them, observing the interaction of the materials, and making adjustments are major components of PIE activities. About the Wind Tube, Mike Petrich said:

> *By playing around we gain ideas about how materials behave in this crazy wind, wind that is spinning and moving around, and just watching how materials behave, and how I can make adjustments to those materials to adjust their behavior [is important].*

For one participant, working with materials in PIE activities evoked a way of manipulating things and learning about things that is lost in much of today's society.

> *…my experience as a child was making things with my grandmother… playing with yarn and fabric samples… PIE is like that.*

The materials available for participants to work with are carefully chosen and provided or presented in a thoughtful, timely way. They allow for a wide range of possibilities of manipulations. Several atelier participants discuss the choice of materials and how critical that choice is:

> *Not only what materials you include, but what materials you do not include and what materials help foster the type of exploration that you are looking for…*
>
> *…it is not a free-for-all of materials, but we look at every single material, and it is not like we take them into every PIE activity. There is thoughtfulness in choosing materials.*

Environment

The environment in which PIE activities take place is well designed and well laid out, to maximize the potential for participants to have rich intellectual design and construction experiences. Nothing is left to chance – the environment is created with care and purpose. The environment includes everything from the way the tables are arranged in the room to encourage people working together, to the choice of lighting and background music, to the way the materials are laid out, to the examples and illustrations from previous projects and models to draw on for inspiration. As Karen Wilkinson explained:

> *There are really subtle things… like for the marble machines. We never do individual materials on the table. We always put them on one side of the room. So the people who are having to walk the farthest actually benefit from seeing the seven marble machines that you see before you get your stuff.*

And as one participant noted:

> *There is something about setting up a space to be able to best facilitate learning and it doesn't mean that there is one recipe of how to do it, but it has to be thoughtful. Where do you put stuff and how is it oriented and what is adjacent to it? How do you partially close off a space so you are not in the middle of this rush of people coming through? And you need to have permission to be able to explore and you need to have places to sit down and… explore longer.*

Facilitation

PIE activities also involve skilled facilitation. Because the activities are so open ended, and because each individual learner is engaged in creating his or her own personal creation, facilitators have to know when and how to intervene so that participants can have the most productive experiences. In the PIE ateliers, we have watched expert facilitators guide us and other participants by knowing when to step in, how to step in, and how to assist people in thinking through their frustrations. Careful facilitators know how not to tell participants the answer, but rather how to ask the right questions at the right moments so that participants are supported in the pursuit of their idea and the facilitator's ideas are not imposed on the process. As one PIE leader said in describing what makes a good facilitator of a PIE activity:

> *There is a certain level of understanding of the activity and the process that you don't have unless you have immersed yourself and done it yourself. On top of that, because the activities are open ended and people come with different skill levels and abilities, being able to gauge where people are in their learning process… being mindful of the fact that it is ok to get frustrated and hit obstacles, but recognizing when something counter-productive is happening…Watching for those moments and giving suggestions at the time that can help them circumvent the larger challenges and take on the smaller ones in a way that empowers the learner – that's a key factor in how we facilitate…*

The following comments from participants highlight the critical importance and role of the facilitator:

> *The path is so important that each person goes through and that is different for everybody, and so there is not really a 'right' way. You kind of have to observe and see what path that person is going on and assist that person without really doing the job for him or for her.*

> *There are what I call "just-in-time" interventions, where you might have one critical artifact that you set down by the participant. And then you say, "Try that. What do you think?"*

> *[Facilitators] don't necessarily jump right into your project… they let you work and struggle through things on your own, and offer suggestions at appropriate times. There is very thoughtful facilitation that takes place during these activities.*

Facilitation also involves framing the activities and constructing the challenges that are put to the participants. As mentioned above, PIE activities are open-ended enough for people to pursue their own interests, but not wide open; they provide enough of a frame or guide within which to construct, but not so much as to be overly constraining; and they provide plenty of room for individual creativity. As one participant noted:

> *The question is broad enough for you to take it in your own direction, but the question and the materials and resources that are provided to you are defined enough where you don't feel like you are just flailing out there trying to figure out something. There is just enough direction, but not too much.*

Kristen Murray, a PIE leader from the Science Museum of Minnesota, explains the different phases of facilitation and the depth of thinking that goes into the facilitation of PIE activities:

> *There's the planning and prep stages, thinking about how the participants are going to be inspired to make something or get involved, either from materials, or examples, or some mini activities that they are going to do first that will build capacity to do something else. And then in terms of the actual contact time itself, balancing the introduction and the facilitator talking part, having enough of that time so people know what the time is for and have a sense of what will happen… And then letting people start to work and knowing when to bring people back together to see something new or reflect together or answering and asking questions individually. There is a real art to that part – knowing when to tell somebody, "you might want to try this, or you could use this material this way"… versus asking a question or pointing out something interesting they were doing. Just asking questions is not the best way to go about it all the time. Helping the participants stay at just the right level of frustration. And then coming back together at the end to celebrate and talk about what they have made is really important.*

Throughout the ateliers, PIE leaders model the facilitation and provide the museum educators with many examples of expert facilitation; afterwards they lead reflection sessions with participants so that they can discuss together this critical component of the PIE work.

Social Context

Another critical element to the PIE philosophy is that participants' individual construction processes take place within a larger social context. There is a careful interplay between participants working on something as individuals and working as a community. Sometimes that involves individuals working in pairs or groups, or individual creations that must be connected to others' work (as in the chain reaction activity). As Mike Petrich explained:

> *In designing the activities, I would say that one of our goals is that there is either a collaborative piece at the end, or the environment and the activity is designed so that we can learn from what each other is doing, whether we are talking or sharing ideas or not.*

A good example of this is the Light Play activity which was developed during the Fort Worth Mindfest atelier, and refined continually throughout the project in work with visitors and with museum educators. At the three-hour ASTC workshop, participants worked in pairs to create individual light and shadow pieces that – once completed – were slid into a large frame that allowed all of the participants' constructions to sit side by side. This created one large art installation at the end of the workshop, which participants could view and appreciate both from the front, and also walk around to the back in order to see the construction and mechanisms.

The PIE approach also includes deliberate opportunities to learn from and be inspired by others. This is truly community design, and design without competition, as PIE institute participants and facilitators noted:

> *You work as a team on projects instead of working competitively. First of all, we were building on our own and had to figure out a solution for how we could make the lamp light up. Then we all connected to each other and we were also working in our group, so it was a nice dynamic going on… That was a really great experience for me and we could learn from each other in this group experience.*
>
> *PIE activities very often are group experiences. So you can look at what others are doing and get ideas from them, talk to each other while you are doing it and see what happens when you make a change to the object.*
>
> *…you are with a group of people who are intrigued and engaged and are good collaborators. You have an opportunity to see other people's work and process, and get ideas from people who have a little more expertise than you do.*
>
> *…learning is really social… for most people. So having a group of people that I can try ideas with and be a learner with helps me.*

Time

Another important element to the PIE work is an intentionally extended time scale – these activities take time to allow people to have deep, rich experiences. For example, the ateliers run three-to-five days. As one PIE leader explained:

> *It is pretty critical that you allow for people to linger and spend a lot of time exploring a lot of different strategies.*

And as participants explained:

> *You need time. Time is an important characteristic of the PIE approach.*

> *A key features of PIE is plenty of time to do what you want to do…*

PIE activities, however, are also flexible enough to allow for different versions in shorter time frames. PIE activities can be done in different settings and time frames – one day versions, one hour versions, and three day versions.

Design Process Matches Participant Experience

From our study of the PIE project, we have seen that the design process for all of the PIE work is thorough, careful and thoughtful. Perhaps most important in discussing the key features of PIE activities is that the process that participants are ultimately asked to go through matches the process that PIE leaders have themselves gone through. PIE leaders spend time exploring materials and phenomena that are interesting to them. Then they think about how to design activities and experiences that allow participants to have similar experiences with the phenomenon and materials. As two PIE leaders described:

> *…people end up doing what you yourself do. For example, in schools, a lot of the way that teachers prepare ends up being what the kids do – the teacher is going to prepare a worksheet lesson, so she is sitting at her desk, with paper and pencil, writing down questions. And what do the kids do? They are sitting at their desks with a paper and pencil and they are doing the exact same kind of work... With the PIE work that we have done, the things we are trying, the ideas that we had, the tools that we used to manipulate objects and test things is very similar to what participants were doing with the materials that we provided for them. So I guess, this is getting at how closely our design process matches what participants are ultimately doing…*

> *…at the heart of our PIE design work is developing activities that we ourselves have become fascinated by because we become involved in a dialogue with the materials. Then we figure out a way to help other people to have an eye on their learning through playing with materials and going through the activities we have developed… We play with it, are around it… It's key if you are going to be a good facilitator of these activities – you have to internalize what the participants are going through…*

Participants know and value the PIE leaders' approach. As one participant said:

> *I think the reason that PIE works is because the people in leadership roles in PIE are inventors and innovators themselves. It all begins with Mike and Karen who are putting dark labs in their closets in their home to try to figure out the next thing that they are going to do with a PIE activity. So my belief is, they create a community of practice, or a community of interest around their work and they provide to that community a materials-rich environment where people can come in and see what they are doing and people can take it into their own perspective, or their own way of replicating the ideas and taking them further.*

We share here an example of the development of the Wind Tube activity that came to life during the PIE Institute project, described by Walter Kitundu[9] of the Exploratorium. This example illustrates how PIE leaders draw on their personal experiences playing with materials to create activities for others. The Wind Tube consists of a fan turned on its back, with a frame on the top made of thin sheets of plastic and embroidery hoops, where participants can place objects in over the fan and watch how they move and react in the column of air.[10]

[9] Walter Kitundu was recently recognized as a 2008 MacArthur Fellow for his inventive work with sound.
[10] Photos courtesy of the Exploratorium. The first photo shows PIE project leaders and staff experimenting as they create the Wind Tube; the second photo shows a visitor engaged with the finished Wind Tube activity.

"PLAYING IT INTO CREATION:"
WIND TUBES, AS DESCRIBED BY WALTER KITUNDU OF THE EXPLORATORIUM

We were talking about doing something with wind. We made air hockey tables and little racers that when you dropped the plywood, the gust of wind would shoot the racers across the table. Then we had this game (designed for pre-schoolers where a small fan shoots fabric butterflies up and out the "nose" of an elephant). We all thought it was a poor take on a good idea, because you couldn't see what was going on inside. So we started to create a version of it using a fan. We turned the fan on end and started putting objects on it to shoot them up into the air. And because it was open, the column of air was unstable, so we tried to enclose it in a tube. We had this ramshackle thing made with dowels and thin sheets of mylar. And we all ended up getting really fascinated with how things moved in there. And there were variables to adjust – what you could put in there, what you attached, heavy, light, if you blocked the air flow. We got to the end of the day and stayed an hour and a half longer than we intended to – we couldn't leave the thing. Then it really struck us that if we are this excited about something so simple, then it has potential. So we tried to refine the design and ended up with the design we have now. And there are a lot of things we understand about it having played it into creation.

CONTRIBUTIONS OF THE PIE PROJECT

We have found that the PIE project has not only served individuals but also made important contributions to the informal science education field. First and foremost, the project has helped to create a leadership tier of museum professionals who have grown significantly in their own understanding of the PIE approach, and in their thinking more broadly about learning. They have also gained new methods, activities and ideas to incorporate into programs and exhibits at their institutions. A few museum educators have also grown substantially in their ability to facilitate and lead PIE professional development experiences for other museum educators.

Secondly, the PIE project has made contributions at the institutional level, leading to new exhibition spaces and program changes that in the best cases have allowed visitors to have important learning experiences similar to those the participants had in the ateliers. And finally, the project has contributed to the development of the capacity of the informal science education field by enriching and expanding the possibilities of what the field has to offer.

Contributions to Participants

Many atelier participants report being deeply affected by their participation in the PIE activities. All of the atelier participants we have interviewed after their participation have been highly positive about their experiences, and they value the learning experience in both professional and personal ways. Specific benefits they mentioned have included experiencing powerful moments of learning and discovery, gaining new insight into inquiry experiences that can be provided in informal settings, increasing their resources to draw from for their work, and gaining specific activities they have been able to implement and experiment with at their home institutions.

Personal Empowerment

The sense of personal empowerment is perhaps the greatest contribution to participants. What participants gain is not so much focused on content as it is on skills and attitudes. They gain confidence in designing and constructing something. They gain confidence in using a variety of materials, and they gain a willingness and ability to playfully experiment with those materials in order to demonstrate scientific principles. Through these PIE ateliers, they also gain confidence in designing activities to implement with others. Participants indicate an increased willingness to take risks, as well as an increased appreciation for the learning that occurs in trying things and having them fail.

PIE gives people the opportunity, experience, ability and confidence to turn an idea into reality. Through trial and error, intention, instruction and the building of fluency, participants experience taking an idea and then making it into a reality. For many participants, being able to imagine something and make what they have imagined is a powerful, crucial experience and one that is lacking in society today.

Several of the participants noted:

> *Students can build whatever they want, and they can develop their own idea; through that they gain ownership of that idea.*
>
> *One piece [of the PIE approach to teaching and learning] has to do with empowerment of the learner, the participant [by] making the stuff that seems technical out there much less so, and allowing people to take some ownership of these ideas. And these skills may range from simple computer programming to soldering, to taking a fanciful idea and embodying it in a piece of work.*

Out of these challenging design experiences comes confidence. As Mike Petrich said:

> *Motivation comes from the confidence that you have if you are successful or if you solve a problem.*

The following survey comments illustrate the sense of empowerment that comes from immersion in the PIE work:

> *Both the firsthand PIE experience as participant (and reflection on that participation), and the feeling of informal but genuine networking with the like-minded but diverse group has been inspirational and empowering. It has given me more confidence in my ideas and work.*
>
> *PIE has changed me as a person and as a professional. It not only has given me an entirely new way of looking at an engineering problem, but also has given me the tools to work my way through it. For an arts person, that is MAJOR. I am now very comfortable with power tools and the engineering process.*

Changing Perspectives on Museum Education

Participants in all three ateliers talked about how their view of what programming and activities in museums can be has changed since participating in the PIE ateliers. They mentioned how much learning occurred for them in the midst of "playing" and tinkering:

> *PIE is a deceptively simple approach, but it has all these ramifications – to the extent where if you think about how you might present or do a presentation in a PIE-like way, you throw convention out the window. I am always thinking now, "How can I do this differently?"*
>
> *It's cliché, but the thinking outside the box thing [applies here]. [PIE] gives adults or students an experience of scientific and artistic thinking that will get them interested, but not in a structured or formal way.*
>
> *I think PIE for a lot of museum educators can be an inflection point into a new way of thinking about a), how you work with visitors, and b) how you think about how you work with visitors and what is important and what may not be as important to you. You might move some different things to the forefront of your activity and you may move back into*

the background. So that is what I would say would be the most important value of PIE: you are changing ways of thinking.

Even for participants who have had more extensive professional development experiences over the years found value in the PIE workshops. As several participants who have participated in inquiry institutes commented:

The PIE work has changed me tremendously. I made a huge mental shift because of this work.

…if I think about a moment in my life where I have had a chance to do things that really inform my practice, and push me to think about things in new and different ways, CILS and working deeply with folks from both TI and IFI would be one, and working with PIE would be another one that I would put for my career and my thinking and my trajectory. It is an inflection point, it is a change. A change in the way I am thinking and what I am interested in and what I want to do.[11]

Part of the value in this experience stems from the fact that opportunities for adults to play, explore and learn either individually or collectively through working with materials are quite limited in daily life:

It was a free-flow environment that worked very well. The facilitation was guided but not restrictive, and the artists were all in there with us. It was a tinkerer's workshop… a touch and feel and experiment environment – all those endangered experiences.

This was so luxurious! I don't have time to do this in my day-to-day world.

Program Improvements

We found that the PIE Institute project has contributed in very concrete ways to participants' repertoires of activities and exhibits that they can bring to their visitors at their home institutions. Participants have gained activities and approaches that they have taken back and been able to immediately use. In many ways, the PIE project has helped create a new genre of activities for museums, a general approach to doing programs and exhibits in new and unique ways. This new genre could have powerful implications for the science museum field at large.

Many participants from the ateliers have taken activities back and implemented them, or designed their own PIE activities based on their experiences in the institutes. They also talked about how they are incorporating the overall approach more into their work – the playful, artistic, inquiry-based method of teaching and learning. The following list represents a mere sample of ways in which participants have begun to integrate PIE into their institutions.

- Staff from the Rapid City YMCA who participated in the Covert Creatures workshop implemented a series of summer camps and after-school classes focused on crickets.

[11] CILS is the Center for Informal Learning and Schools; TI is the Teacher Institute, and IFI is the Institute for Inquiry. All three are programs housed at the Exploratorium.

- Staff from Discovery Science Place in Tyler, Texas who participated in both the Art Machines and Mindfest ateliers have designed classes for school groups in conjunction with an exhibition on sound that incorporate activities from the PIE ateliers.
- Participants from the St. Louis Science Center are incorporating an art robots activity into a robotics class.
- Staff from Omniplex have been using light painting with their teenage volunteers, doing demonstrations on the floor of the museum.
- Staff from the Imaginarium of Southeast Texas have been taking activities learned during the Mindfest atelier to schools in rural communities as part of the museum's outreach programs.

In addition, atelier participants are offering new programs and enhancing existing programs at their institutions based on their PIE experiences. Because the materials are inexpensive, participants were able to immediately try things at their own institutions:

> *I was just full of gumption coming back [from Explora!]… I really like that with a low budget you can make so many creative things – simple machines – tinkering with just materials that you get from the salvage store or from our recycling area where we gather materials. I didn't need to purchase a lot. I built some cardboard automatas and the wind tube and the wind mills. And I want to do a scribble machine. I had pretty much everything already there and didn't have to order a lot.*

Survey respondents indicated that they were offering numerous PIE-related programs at their own institutions following their participation in PIE ateliers. At the time we administered the survey, 22 respondents reported on 61 different PIE-related programs in the past year, serving thousands of visitors including youth in after-school programs, home-schooled youth, the general public, college students, teachers, and school groups. A sample of programs reported on the survey include:

- Y-Bot Crickets – an after-school course for kids that introduces them to Crickets
- Mark Makers – a program for college-level physics students
- Frankenstein Bugs – a program for 7-8 year olds who examined bugs under a microscope, then invented a new bug using motors and Crickets
- Mindfests – multiple institutions hosted some form of Mindfest that involved PIE-inspired programming for the general public; these events generally involve visitors totaling in the thousands on a particular day at the museums
- Cricket Chain Reaction – where youth work on a chain reaction through the classroom using found objects and Crickets
- Inspiring Inventors – a year-long partnership with an elementary arts magnet school where teachers and students integrate arts and engineering with crickets
- Sound and Light Exploration Tables – set up on museum floor for the general public to do PIE-related activities
- DesignIT Studios – a year-round after-school program for teens, directly based on PIE activities

- XTECH – a program that provides art, science and technology education to underserved students through after-school programs and summer and weekend workshops, using PIE activities as the curriculum

The following survey comments indicate the extent to which PIE has influenced programming at participants' institutions:

> *I have modeled investigations I have facilitated with students and teachers on experiences I had at the Art Machines Atelier.*
>
> *It benefited our programs, especially our summer and home-school labs, by adding a more "in-depth" experience for the kids, allowing them to program and explore in a direction guided by their own ideas, not ours.*
>
> *The PIE workshop has informed my interest in creating an environment that nurtures experimentation, mistake-making, exploration, and guided learning. By experiencing my own learning process in this environment (set-up in the PIE workshop), I am able to develop projects and classes that embody these ideas.*
>
> *It has changed the experience for our visitors. Just recently one mother said that our MindFest Spring Break day "was the greatest day" – we have begun to hear more of that.*
>
> *PIE has opened up doors for us to do more sophisticated programming from the perspective of technology as well as the depth with which visitors dive into materials and use them to make their own stuff.*

Leadership Capacity

For a few of the atelier participants, and particularly, staff from partner institutions, one of the main benefits of the PIE Institute project has been an increased capacity to engage other museum professionals in meaningful PIE professional development experiences. For these participants, not only have they grown in their own personal learning and in their capacity to facilitate PIE experiences for visitors at their own institutions, but they have also gained in their facilitation skills and have become more expert at guiding other museum professionals through PIE experiences.

Perhaps the best example of this is Kristen Murray, a partner museum staff member from the Science Museum of Minnesota. Kristen is quite skilled in her ability to lead museum educators through PIE experiences. This has been one of the most beneficial aspects of the PIE project for her:

> *The opportunity to practice and to work with this group of mentor/peers, to see how they do it and plan things with them [has been valuable]. Finally I am able to see all at the same time the materials and the activities that will empower people to do the "big" activity and how people will reflect and share at the end. Just practice and talking with*

> *people [is valuable]. The opportunity to get to meet more people who have participated in PIE workshops and learn a bit about how they facilitate PIE activities has been great as well… The other thing is being a little more grounded in what my facilitation philosophy is and being more confident about it… I am younger than a lot of the participants… Just feeling confident that I can learn from them and they can learn from me.*

Contributions to Institutions

There have been several examples of the PIE influence and contribution being more widespread than solely for individual staff members. Institutions have adopted the PIE philosophy more broadly and are applying it throughout the museum, not only to programs but also to new exhibitions spaces. Or, the PIE philosophy so complements the work they were already doing that it has allowed them to strengthen and deepen their public offerings. These broader institutional benefits include the creation of new exhibition spaces and programs, new staff development programs, and a change in mindset about what museum education is. These changes benefit visitors as they are given opportunities to experience profound learning experiences similar to those the atelier participants have had.

Project leaders have been quite strategic in selecting atelier participants. They have invited teams of participants from museums, which offers greater assurance that participants can return to their home institutions and have support to begin to implement these activities at their sites. Project leaders have also been able to strike a balance of breadth and depth in their institute participants. For example, some institutions who have engaged in more extensive work with PIE activities have had staff attend multiple PIE offerings, deepening their understanding and experience with PIE.

We include here vignettes about the influence of PIE on several institutions: The Children's Museum of Houston; Explora! (a partner institution in this grant); Reuben Fleet in San Diego, and the "host" institution, the Exploratorium.

THE CHILDREN'S MUSEUM OF HOUSTON

To provide an illustration of broader institutional contributions we describe the example of the Children's Museum of Houston. Several staff members from the museum have participated in many of the PIE offerings at ASTC and in the ateliers. In addition, the museum hired Mike and Karen, along with Diane Willow from the Science Museum of Minnesota, to consult with them on the development of a new exhibition space based on PIE philosophies. As the Director of Education noted:

> *PIE has opened up doors for us to do more sophisticated programming from the perspective of technology as well as the depth with which visitors dive into materials and use them to make their own stuff.*

The museum has been working for the past several years on an expansion of their exhibition spaces. Part of that expansion includes a space called Invention Convention which has been

influenced significantly by PIE. Slated to open in 2009, the museum will offer workshops and tinkering in the space.

PIE has also contributed to new activities, such as cardboard automata, being incorporated into existing programs. In addition, the Director of Exhibits said he models the professional development he does with his staff on PIE:

> *Anytime I can add in an open ended experience, I add it in. I want everyone to feel this way – exhausted and re-energized at the same time. Even if it is one of the discovery guides who is going to leave this museum in a year, I want them to have this experience, because they will leave here and take it with them. And if they go into education, I want them to teach this way.*

And the director of the Community Science Workshop (CSW) at CMH is also using PIE activities in her weekly training sessions for her five coordinators.

This museum definitely benefited from having multiple staff people attend PIE ateliers. Staff reported forging partnerships and relationships with one another as well as with the idea of PIE while at the ateliers. As the CSW director said:

> *We found out at the atelier that we have similar philosophies and ideas. We can work together better now because I know what [my colleague] is capable of.*

Perhaps most importantly, PIE has inspired staff at this institution to take risks. The atelier participants we interviewed at CMH all reported an increase in their confidence because of PIE. They said they were much more willing to try out a programming or exhibit idea with visitors rather than not try it, as these quotes from three different staff people illustrate:

> *Let's find out. Let's experiment and see what we come up with!*

> *In the past, I had ideas and I didn't see them through because I was worried they might not work. I have the confidence now that I am on the right track. I take some risks.*

> *I try all kinds of new things now.*

EXPLORA SCIENCE CENTER AND CHILDREN'S MUSEUM OF ALBUQUERQUE

Explora Science Center and Children's Museum of Albuquerque is another illuminative example and was one of the partner institutions in this project. The philosophy of this museum is very compatible with PIE – they were already doing highly-facilitated, materials-based exhibits and programs in their unique museum space and offering professional development workshops to other museum educators to share their philosophy. In this case, PIE built on an existing institutional philosophy and allowed individual museum educators to deepen their practice.

Like the Children's Museum of Houston, having multiple staff participate in PIE ateliers has benefited Explora. As one staff person said:

> *I think that a variety of people participated at different ateliers and it has actually been really good, because we are all so different and so you are getting a take on what PIE is about from a variety of different personalities.*

Perhaps most notably, PIE also contributed to the development of two new, highly innovative exhibit spaces for visitors. Both of these studio spaces are walled off from the main exhibit hall, but have sides and doors that open out to the rest of the museum. Both of these spaces are facilitated full time.

One space is called Systems in Motion. Here, visitors can create automata, and construct things with pulleys, gears and cams on a dual-sided pegboard in the middle of the room. Delightful illustrations and diagrams of how these mechanisms work line the walls. Shelves line one wall, where visitors can find pre-built pieces to tinker with and can store their creations. There is also a separate tool area with hot glue guns and drills.

The second space is a Chain Reaction studio. In this space, visitors can individually and collectively explore making chain reactions. This space includes a chalkboard for working through ideas; two corner workbenches with glue guns, toolboxes, motors, wires, etc.; and two computers with Cricket programs. A hanging metal "power source" in the middle of room with wires hanging down allows visitors to plug things in. Bookshelves along one wall contain small red organizing tubs labeled with supplies, like nails, brads, paper clips, popsicle sticks, pipe cleaners, batteries, marbles, etc. Large storage shelves hold larger supplies, like wooden blocks, recycled items of plastic, metal, wood, paper, plastic tubing, funnels, and tape. The center of the room contains eight rolling work tables that can be moved around in limitless configurations in the room, each with two removable plywood tops so projects can be attached and saved on shelves for people to come back to. Each of these tables also has a slide-out shelf on which visitors can create two-level and larger reactions.

The new exhibition spaces are popular with visitors. During the PIE atelier held in Albuquerque, we observed a high school physics class working in the Chain Reaction Studio, building chain reactions, and setting them off with facilitators and their teacher. As one parent we observed in the Systems in Motion studio said about the type of learning the new exhibit spaces provide:

> *It's the kind of play that's building on their curiosity of how the world works. It's a mature kind of play.*

In addition to the new exhibit spaces, PIE has influenced existing programs at Explora! as well:

> *It has benefited our early childhood program… they are actually now going to do the wind tube that was in the PIE booth at ASTC.*

Overall, PIE has fit nicely with an existing philosophy at this institution:

> *I hope more people see that value in having your visitors sit and engage in an activity that is presented that they can add to and make their own. PIE is so wonderful because*

> *you can have the same stuff out, but things aren't ever going to be the same... Now that the chain reaction area is open, people will ask us, "Can we save this until tomorrow and come back and work on it?" How exciting is that?!*

REUBEN FLEET SCIENCE CENTER

Another institution that has been influenced by their involvement with PIE is the Reuben Fleet in San Diego. One staff person noted that the museum recently converted a space that used to involve staff giving demonstrations to visitors into a space where visitors can sit and engage in PIE activities, such as creating scribble bots:

> *We saw people sit down and do these activities. So the area becomes less of a demonstration area where I present something to the public and more of an area where they can come and participate for a length of time, doing an activity that is more inquiry based.*

Staff have also shared PIE activities they have engaged in at ateliers with other staff at the Reuben Fleet:

> *Following the workshop that I went to, I immediately starting gathering materials and supplies and getting things ready for the training which I then did for my staff. I had them go through the experience and then we sat and talked.*

Staff at the Reuben Fleet said that PIE-based work is having a significant impact on the experiences of staff and visitors; one staff person estimated that a quarter of the work happening at the Reuben Fleet is based on PIE.

THE EXPLORATORIUM

The impact of the PIE project on the Exploratorium has been interesting as well. The PIE project has resulted in new programs and exhibits for the public; an infusion of energy and spirit for Exploratorium staff; and the infusion of PIE ideas into other programs at the museum and other networks the Exploratorium works with.

PIE leaders have offered workshops and public programs on the floor at the museum, including the PIE Chain Reaction day, marble machines, wind, and light play. As one long-time Exploratorium staff person said:

> *All of a sudden, there are little guerilla exhibits on the floor that come out of the PIE workshop – a drinking fountain that makes music! These things are delightful for visitors and they bring people joy. Then there are events that take place on the floor – the PIE day, recently, was really quite fun. Both immediately add to the interest of the visitor for this place, and provide the inspiration and vision for other kinds of things that might happen on the floor here.*

They have also provided professional development to staff from the Exploratorium who are engaged in using PIE activities in their outreach efforts. For example, staff leading the museum's XTECH project for middle school-aged youth participated in PIE ateliers, and PIE staff have helped train facilitators in leading PIE activities with the XTECH youth.

For some long-time Exploratorium staff, PIE has brought an energy and spirit reminiscent of the museum's beginnings. As one staff person said:

> *[PIE] is bringing back something that I had when I first started working here – the connection between art and the other things we do here and the power of that connection. For a number of reasons, that has gotten a little lost in the other work I am doing. This whole emphasis on creativity is another piece that tends to get lost in the push of the work we do with schools and the emphasis on the needs of the schools. Creativity and the value of that gets kind of pushed to the background. So bringing that back to the foreground has been important. And on a very practical end, some introduction to new materials, new kinds of activities, pieces of which sneak into the other work I am doing.*
>
> *There is a lot of attraction here to this work. My feeling is that the PIE program embodies a lot of the spirit of the early days of the Exploratorium. And some of that, when you get involved in trying to meet deadlines and get people through the gate and write proposals and fulfill those needs, that can get lost. I think people recognize that the kind of thing PIE is trying to do embodies that spirit and that is why they are here. The Exploratorium thinks of itself as R and D for other museums – PIE is the R and D unit for the R and D place.*

The Exploratorium is also sharing PIE through its networks and partnerships. The TexNET network of museums in Texas will focus on tinkering in its professional development and exhibit work in the coming year; all of its members have participated in PIE ateliers, and tinkering activities will be a focal point to the work. In the ExNET partnership, one of its museums is opening a tinkering workshop, and the newest ExNET exhibition that began traveling this summer is a tinkering exhibition; the professional development that will be provided to ExNET partners in connection with this exhibition will be based on PIE experiences and PIE leaders will be involved in the professional development:

> *…We are going to probably bring out a couple of the Minnesota folks, Kristen and I think Keith might be going out to Montana to work with one of our ExNET partners, which will open up all of our ExNET partners to go out and do some PIE activities. So we are going to try and utilize some of the great professional developers to work with our ExNET team.*

These vignettes illustrate the ways that PIE has made important contributions to these institutions. PIE has been influential in these institutions in both broad and deep ways. We think it is important that PIE is influencing both staff development and visitor experiences through new exhibits and programs. Most importantly, we think it is significant that staff at these institutions are approaching their day-to-day work in new ways based on their experiences with PIE.

Contributions to the Larger Informal Science Education Field

In addition to contributing to individuals and institutions, the PIE Institute project and its predecessor, the PIE Network project, have contributed a great deal to the larger field of informal science education as well. The Exploratorium has a long history of sharing its innovations widely with the field. The PIE project has been no exception. Through the ateliers, workshops, inventive exhibit booth at ASTC, website, and involvement of network members as participants in the PIE work, the PIE project has shared its thinking and spirit widely with the field. Museum educators in the field gain energy, new ideas, and enthusiasm from this work.

PIE Website

The website is a particularly valuable resource to the field. It documents the project, including detailed notes about the work of and thinking behind the ateliers, as well as PIE activities and ideas that people can implement at their own institutions. The photographs are particularly compelling – each PIE activity has been extensively documented through photos, and the photos are revealing glimpses into the wonder and engagement of PIE. As participants noted:

> *Their website is great. It is very well thought through, and you can see that they dry tested a lot before they put it out there and so you could take it from there and do it.*

> *…the idea generation that comes out of PIE is extremely valuable and being able to go to their site and look at the stuff that they have done or participate in their workshops, really helps in bringing new activities and things to our museum. The amount of brain power that they have in coming up with new and creative things to do makes it that much simpler for us to incorporate the kinds of things that we want to do in our museum.*

PIE leaders also have extended the reach of the project by drawing participants from existing networks and collaboratives in the informal world, many of which had previous connections to the Exploratorium. These include museums from the ExNET and TexNET collaboratives, a collaborative of institutions in Arkansas, and participants from the LIGO center. Having participants from existing networks and collaboratives contributes to a broader dissemination of PIE activities as participants can share what they have learned from these institutes not only with staff at their home institutions, but with professionals from museums involved in their networks as well. PIE has also attracted international participants, with museum educators from Germany, Canada and Iceland participating in ateliers.

For many, PIE is viewed as a unique and valuable resource for the field. Of those responding to our survey, 95% indicated that the PIE ateliers have been better than other informal science education professional development they have attended. The following survey comments from atelier participants illustrate this:

> *Very seldom do I find workshops that so immerse us into an environment of pure creative development. In addition, the depth and lengths to which we worked and the collaborative work was phenomenal.*

Other professional development experiences have been quite passive in comparison – listening to abstractions of others' experiences. PIE is the process itself and a model of an effective constructionist environment on many levels. Because of that it was practical and extremely useful.

PIE is providing experiences for informal science educators that aren't available anywhere else. We have heard from participants an excitement and energy for the PIE work that we don't often see from other professional development experiences. Comments from several people we interviewed include:

Three years ago, there was nowhere to go for this kind of learning.

I would say it is both pretty unique and pretty valuable. I don't know of anyone else out there doing this kind of work.

There is a different element to this PIE that stands out amongst, even amongst the most inquiry types of stuff. The inquiry stuff can be very guided at times and I think that the PIE takes a very different approach to it. There is an element of creativity that is in PIE that is not found in a lot of other activities or things that are going on in the museums.

…a lot of us in our field exist in this rat trap mode where we have so many things going on, or we are trying to move so fast that we don't get the depth opportunity and to me, PIE is that. You are taking some precious time and you are dedicating it to a singular focus on being able to learn more about something that will be extremely valuable to you back at your institution and to your visitors.

I really feel like what the field needs is opportunities to think deeply and richly about new ways to advance the field and advance our impacts on visitor learning and that needs to happen in such a way that it is not only reported out as a conference or becomes part of a chapter in a book. It needs to happen in a way where people can participate with it, because that is the way that people advance their own practice… [To have them] jump in there with me and do it with me for a little bit gets me miles further than just reading something.

I think there is a real difference between an activity that keeps someone busy and an activity that gives people the tools or changes the way they think about things. It may not be tangible the afternoon after the activity, but it affects the way people see the world or imagine what is possible. In a lot of the museum field, the activities are based on one particular phenomenon or one way of illustrating a craft or activity…. These tend to be one dimensional in the sense that there is something they want to get across, and once that is gotten across, people move on from there. PIE, even though it may be messier to dive into, introduces the idea of the process of learning (rather than just doing an activity). There are larger benefits that can be reached by engaging in a longer term, more substantive, open ended investigation of phenomenon…

In summary, PIE has had a profound influence on participants, their institutions, and the larger ISE field. The simple yet innovative approach to teaching and learning espoused by PIE has advanced the field. The care taken by PIE leaders in creating activities that are meaningful and in designing professional development experiences for ISE educators has led to innovations in programs and exhibits that benefit museum visitors across the country.

CHALLENGES AND OPPORTUNITIES

While the PIE project has been highly successful, there have been several challenges the project has faced, and there are also newly emergent opportunities for future work.

One challenge for PIE leaders is how the integrity of PIE – the philosophy and approach to teaching and learning – is maintained, or not, as the PIE work gets translated by other museum educators and put in place at their institutions. There is clearly a challenge here in translating what happens in a day or two days at the ateliers into meaningful experiences for a lot of people in shorter time periods. Frequently, the focus becomes moving large numbers of visitors through PIE activities in a short amount of time; or the involvement of visitors in actually constructing something gets removed, which alters the experience. As one education director noted:

> *One of my personal concerns is our ability to do justice to the work. I am nervous about us keeping the purity of the idea. They are so grassroots and come at things from a more artistic side, whereas we are more entrepreneurial and approach things from more of a business model. Our personality is more how can we systematize the implementation? Can you do both? Are we watering down the value of this by approaching it this way? Can we get more towards an artistic mindset without giving up too much of our business mindset that has helped us get where we are?*

A PIE leader explained the issue this way:

> *…[It is a challenge to] not be so numbers-conscious but rather more conscious of the value of the experience itself… the experience of the participant. To me, it is much better to have 25 people leave with a really rich experience in the afternoon and a deeper understanding, just a deep engagement with it, than to have 100 people run through with a tacit understanding. It comes down to patience. PIE isn't easy… PIE isn't entertainment…*

We wondered if this challenge presented an opportunity for the project to build in more mechanisms to collectively work and reflect on the work together. The project placed few demands on participants to be reflective practitioners with them – there were perhaps not enough feedback loops built into the project whereby people could return to their institutions, try things, and reflect with PIE leaders about those experiences. Perhaps some sort of peer critique and review process or sharing would contribute to moving the work forward.

Another challenge comes for participants in the barriers they face in trying to successfully implement PIE activities at their home institutions. Participants responding to the survey indicated that lack of time, lack of experience with PIE, and the cost of materials were the main barriers to doing more with PIE than they are currently doing. Survey comments related to these barriers include:

> *I don't feel confident enough (on an individual level) in my experience with PIE activities to implement them at my institution. I would like to attend more workshops and learn more.*

> *We are very small so staff and money are our big limitations. I would love to attempt to take this out to the schools, but have no idea how we would do that.*
>
> *On an individual level it seems like PIE principles are not immediately evident. Conveying these principles takes some time and practice. Institutionally, PIE activities are demanding. To implement PIE-like activities on a daily basis requires good training and great employees. It's absolutely possible if people are committed.*
>
> *[Barriers include] getting participants. This is a pretty expensive program to be able to run. It is very supply and staff intensive. We use many recycled materials and encourage the students to not waste. I do feel cost is an issue for parents signing up their children.*
>
> *Having the time to play with the ideas.*

In addition, a few participants noted that the focus of their institutions is simply too limited to do as much with PIE as they would like; there is not the space or opportunity to implement additional PIE-related programming.

Another major challenge for the project emerged in working with partner museums – Science Museum of Minnesota, Explora! and Fort Worth – on the ateliers they offered at their institutions. There were several instances at the ateliers where PIE leaders and partner staff could have worked more closely together to reflect on the process. In this way they could have created stronger experiences for participants, and further built the leadership capacity of the partner museum staff to offer PIE professional development experiences to other educators. This was less of an issue at the Science Museum of Minnesota than it was at the other institutions.

Learning how to facilitate PIE professional development experiences is difficult and takes a great deal of time. Only a handful of project leaders participating in this project have truly developed those skills. There is an opportunity and need for further work facilitating the thinking about the learning at this level, to develop leaders who can expertly facilitate PIE professional development for other museum educators. The PIE Institute project began to grow this capacity, but more work needs to be done. As one participant noted:

> *I would love to see more folks comfortable and able to lead real, true, PIE professional development workshops, as opposed to just going out and leading the activities of PIE.*

Another challenge that has emerged for PIE leaders and participants is in describing the value of this type of learning. Participants report returning from PIE institutes and sometimes finding it difficult to articulate the type of learning they have experienced and its value. Participants sometimes face an uphill battle convincing their institutions to invest in this philosophy. The challenge and opportunity for PIE is to continue to find ways to document and share the value of the powerful learning experiences the PIE project provides.

The Opportunity to Continue Building a PIE Network

Finally, we see a tremendous opportunity and need that has emerged from this project. A learning community of practitioners has been created around PIE – a group of educators who want to continue to learn from the Exploratorium and partner museums, as well as from one another. This community could be the solid foundation of an ongoing network of museum educators interested in doing more, and better, PIE work at their own institutions. What is needed is a mechanism by which these practitioners can share ideas with one another, and have continued opportunities to have personal PIE learning experiences.

One theme that has resonated throughout all of our interviews and survey work is the extent to which people would like more opportunities to engage in PIE work with project leadership and with other PIE atelier participants. As one survey respondent noted when asked what more the PIE project could offer said:

> *1) MORE WORKSHOPS!; 2) MORE WORKSHOPS!; 3) residencies where participants can come study with Karen and Mike; and 4) regional PIE meetings where the energy and learning can be sustained between ateliers.*

On the survey, many participants rated highly their interactions with PIE leadership and other participants. This indicates there is a group of people ready and willing to continue to develop their own learning, as well as that of the group, through PIE-related activities. Several participants suggested creating a PIE listserv:

> *I was wondering if we could just start a listserv for PIE… I think then that you feel like you are a little community…but it is really hard to keep on working on it… so if you can read about the successes…. You kind of have to bounce off your ideas with others who already have more experience.*

In particular, there is a desire among participants for mechanisms to contribute to a PIE network: a place to share ideas, failures, lessons learned, and to reflect with their colleagues. As one participant noted:

> *I would love to see more user-generated work shared out.*

SUMMARY

The PIE Institute project has been highly successful. The PIE leadership's commitment to doing thoughtful, careful work, and to inviting a growing number of practitioners in to share that work with them has been worthwhile. The project has consistently provided powerful, "flow" learning experiences for museum professionals, who in turn, have returned to their institutions and attempted to provide similar types of learning experiences for their visitors.

In our evaluation work over the years, we have rarely seen the kind of energy and enthusiasm about a project that we have seen with PIE. The professional development experiences the project provided have had lasting and profound effects on the participants. Participants have been highly articulate in reflecting on their PIE experiences and the value of those experiences – and that articulateness reflects on the deep nature of the PIE work they have been engaged in. The innovative website, ASTC workshops, and tinkering studio booths at ASTC have brought new life and energy to the informal science education field.

It is very rare that projects in informal science education are truly innovative. The PIE Institute project has been exactly that, and the innovations the project brings to the ISE field are needed and important. We see tremendous value in the energy and enthusiasm the project inspires, the creativity and whimsy, and the profound, empowering learning experiences the project has provided. We see a tremendous opportunity to continue the growth of the PIE community and we hope that NSF and other funders will provide support to build upon the foundation that has been put in place.