The PIE Network

Promoting Science Inquiry and Engineering through Playful Invention and Exploration with New Digital Technologies

A proposal from:
MIT Media Laboratory, Science Museum of Minnesota, The Exploratorium, American Visionary Art Museum, Fort Worth Museum of Science and History, Lemelson Center at the National Museum of American History at the Smithsonian Institution, MIT Museum, and Center for Children and Technology

1. The Need

New digital technologies are becoming widely available in homes, workplaces, schools, libraries, and community centers. But rarely are these new technologies used to engage people in meaningful scientific inquiry. Too often, students in science classrooms use computers merely to look up information on the Web.

To address this problem, the National Science Foundation has, for many years, funded research on new technologies designed to support scientific inquiry and learning. Some of the most successful projects have used new technologies to blur the boundaries between science and engineering, helping students become engaged in scientific inquiry not only through observing and measuring but also through designing and building.

In a series of NSF-funded research projects (NSF grants 9358519-RED and CDA-9616444), for example, the MIT Media Laboratory developed “programmable bricks” (tiny computers that connect to motors and sensors) that pre-college students then used to build their own scientific instruments (Resnick et al., 1996). Among their creations: an odometer for rollerblades (using a magnetic sensor to count wheel rotations); a diary-security system (using a touch sensor to monitor if your brother is snooping in your diary); an automated hamster cage (using a light sensor to keep track of what your pet hamster is doing while you’re asleep).

Research studies at pilot sites (including schools and community centers) found that the students not only became more motivated in science activities, but also developed better critical capacities in evaluating scientific measurements and knowledge (Resnick, Berg, and Eisenberg, 2000). In the context of their design projects, students continually developed hypotheses, collected relevant data, and iterated their design ideas based on the results. While working on these projects, middle-school students learned engineering concepts (such as feedback and control) that have traditionally been taught only at the university level. These concepts are important for understanding not only classic “engineered systems” but all types of systems – ecosystems, chemical systems, social systems.

The programmable-brick technology became commercially available in 1998, as part of the LEGO MindStorms products, which are sold in toy, electronics, and educational learning stores throughout the country. These products have been very successful, putting this NSF-funded technology into the hands of millions of people. But major challenges remain. Many people still do not have access to this new generation of technology. And even when people do have access, they tend to use the technology in limited ways, mechanically following step-by-step instructions rather than becoming engaged in the processes of invention and inquiry. As a result, few people make deep connections to the scientific and engineering concepts associated with these new technologies and activities.

2. Goals

- To engage a broader audience in science inquiry and engineering, by enabling more people to create, invent, and explore with new digital technologies
- To make research-based educational technologies, and the ideas underlying those technologies, accessible to larger and more diverse audiences
- To promote the value of "artistic invention" and playfulness in science learning
- To provide meaningful feedback to researchers who develop new educational technologies and activities

3. Project Description

We propose to establish a network of museums, working in collaboration with the MIT Media Laboratory, aimed at disseminating and supporting more constructive uses of new digital technologies. The network will focus on helping the general public learn to use new technologies to create, invent, and explore – hence the name: the Playful Invention and Exploration (PIE) Network. By taking a playful approach to invention, and integrating engineering with artistic expression, the PIE Network aims to reach a broader and more diverse audience, providing support for a wider range of people to see themselves as inventors.

In most science-education settings, there is a sharp division between the physical and the virtual. There is a rich tradition of using physical materials for hands-on science inquiry, but that tradition has had little influence on the ways computers are used in educational settings (e.g., Eisenberg and Eisenberg, 1999; Druin and Hendler, 2000). The PIE Network aims to bridge this divide, introducing new technologies and activities that fluidly link the use of physical materials with digital technology in creative inquiry and inventive exploration.

Collaborating institutions of the PIE Network will be involved in the following activities:

3.1 MindFests. PIE museums will organize MindFest events, aimed at bringing together "playful inventors" of all ages. MindFests are intended to forge connections among local inventors, hobbyists, teachers, artists, and young people and their families, providing a forum where they can participate in new types of invention activities, try out new technologies (including prototype technologies from the Media Lab), share their ideas and creations with one another, and develop deeper understandings of scientific and engineering concepts.

The MindFest events will be based on the very successful two-day MindFest held at the MIT Media Lab in October 1999. But each museum will adapt the format and style of MindFest to fit its own institutional goals and strengths.

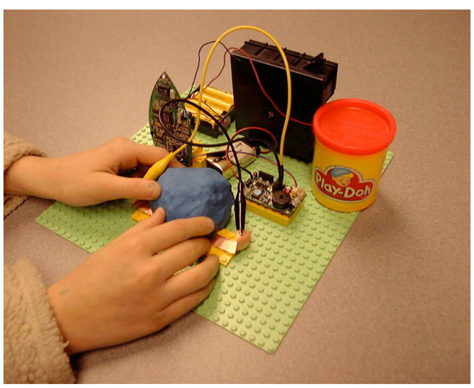
In general, MindFest events will include four sets of activities:

- a Construction Zone filled with various types of construction materials, programmable bricks, and art supplies;

- Make-Your-Own Workshops, such as Make-Your-Own Musical Instruments, Make-Your-Own Interactive Animations, and Make-Your-Own Homebrew Sensors;
- an Exhibition Hall where participants can display their creations and inventions;
- lectures and panel discussions, focusing on the role of "invention" in learning and creativity.

At the original MIT MindFest in 1999, some people spent most of the weekend in the Construction Zone. Some built conventional robots, but others used craft materials and programmable bricks to make computerized jewelry and hats that they wore throughout the weekend. Some people started with a 90-minute Make-Your-Own Workshop, but then continued to work on related projects through the weekend, taking breaks now and then to attend a panel discussion. Throughout the event, children and adults worked together on projects in workshops and in the Construction Zone. In the Exhibition Hall, it was common to see children and adults in animated discussions about their inventions. Adults came from a wide range of backgrounds: teachers, scientists, engineers, toy designers, artists, museum educators, inventors, and robot hobbyists. In the "Town Meeting" at the conclusion of MindFest, and in email messages following the event, the feedback was overwhelmingly positive.

As PIE museums organize their own MindFests, learning from the MIT experience but adding their own imprint, we hope to reach a larger and more diverse audience, drawing a wider range of people into the "playful inventor" community. In particular, future MindFests will be designed explicitly to attract families from under-served communities – and families who have not traditionally been engaged with (or interested in) technology-related activities.



Musical instrument from MIT MindFest, made with a Cricket, MIDI board, and simple Play-Doh sensor

3.2 Make-Your-Own Workshops. The PIE museums will offer Make-Your-Own Workshops not only at MindFest events but throughout the year, integrating these workshops into their ongoing educational programs, to provide ongoing access to PIE technologies and activities. Many museums, of course, already offer successful hands-on workshops, and some even offer computer-based invention workshops (using, for example, the commercial LEGO Control Lab technology). Our new workshops will build on this tradition, but will open up new possibilities by integrating the latest computational technologies (such as programmable bricks) with traditional craft and construction materials.

The MIT Media Lab developed a few prototype Make-Your-Own Workshops for the original MindFest event, but work is needed to refine these workshops and to develop others. Each of the PIE museums (in collaboration with the Media Lab) will develop new Make-Your-Own

Workshops, drawing on their own areas of expertise. The museums will then share these workshops with one another.

We believe that these Make-Your-Own Workshops can help bridge the gap between artists and engineers, making possible new types of "artistic invention" projects. In some workshops, participants will make innovative use of traditional craft materials – for example, creating their own night lights, using strings of holiday lights, flexible straws, colored filters, batteries, and paper clips for switches. In other workshops, participants will make use of newer technologies – for example, using sensors and programmable bricks to control when their night light turns on (at a pre-determined time, or when a person approaches), or to start a small fan that sends a breeze their way during hot summer nights. In yet other workshops, participants will develop artistic creations on the computer screen – for example, using the Media Lab's Design-by-Numbers software, available for free on the Web (Maeda, 1999).

Many of the Make-Your-Own Workshops will make use of the Media Lab's "cricket" technology, a family of small, lightweight programmable bricks that can be easily integrated into everyday objects. This technology has been developed through Media Lab research over the past four years, and continually revised based on results from pilot projects in classrooms and after-school settings. The crickets, unlike commercial programmable bricks, are designed to work together as a system, so it is easy to add new "peripherals" for capabilities such as speech-synthesis, radio-communication, and heart-monitoring. We also plan to develop Make-Your-Own Workshops that take advantage of the rapid-prototyping technologies (such as 3-D printers and laser cutters) that have been used extensively in design courses and projects at the Media Lab over the past several years. We will seek additional (non-NSF) funding to acquire these rapid-prototyping tools for some of the PIE museums (and to develop new software and activities to make these tools more accessible for the general public).

3.3 Dissemination. We have several different strategies to make sure that PIE ideas and activities (and PIE "ways of thinking") reach beyond the PIE museums themselves.

3.3.1 PIE Project Pamphlets. The PIE museums will develop a collection of PIE Project Pamphlets to help people get started on playful-invention projects in homes, schools, and community settings. The pamphlets will provide examples and process descriptions of PIE projects (mostly from Make-Your-Own Workshops), advice and stories from people who worked on the projects, suggestions on how to get the necessary tools and materials, illustrations of the scientific and engineering concepts underlying the projects, and suggestions for related projects. Designed to visually communicate both the spirit and content of PIE, the pamphlets will be based on a common template for consistency, but will reflect the styles of the individual museums. Pamphlets will be shared across museums within the PIE network, distributed more broadly at an ASTC conference workshop in 2003, and available at Make-Your-Own Workshops, MindFests, and other PIE events.

3.3.2 Online PIE Idea Library. The projects and stories from the PIE Project Pamphlets will also be available on the Web, in the PIE Idea Library. We will take advantage of the affordances of the online medium to provide videos of projects, search capabilities for finding projects matching personal interests, and "invention maps" showing the paths of exploration, lines of investigation, and problem-solving strategies used in the invention process. Staff at the PIE museums will develop the initial online examples, but the Web site will enable others to submit their own invention stories and examples. In developing the PIE Idea Library, we will draw on the lessons learned from the Science Museum of Minnesota's Thinking Fountain, which involves educators, parents, and students in sharing activity ideas. Based on our previous experience with science-museum Web sites, we expect to get more than a million visits to the PIE Idea Library over the course of this project.

3.3.3 PIE Contributions to Traveling Exhibition on Invention. To extend the experience of MindFests and Make-Your-Own Workshops to a broader audience, the PIE Network will contribute to the *Invention at Play* exhibition, being developed by the Lemelson Center, with exhibit developers from the Science Museum of Minnesota. The 3,500 sq.ft. exhibition, scheduled to open at the Smithsonian's National Museum of American History in Washington DC in June 2002, will make use of the Smithsonian's rich historical collections to engage visitors in the playful side of invention and the inventive side of play. The exhibition will be toured to nine science centers and museums nationwide by the Association of Science-Technology Centers (ASTC). The PIE Network will help develop components for the exhibition, and also provide resources that will help museums on the tour plan their own MindFest events.

- *Exhibit Charette.* In spring 2001, the Exploratorium will hold a 3½-day charette (an intensive working design meeting) to develop open-ended exhibit components for a staffed program space within the Lemelson exhibition, based on MindFest Construction Zones and Make-Your-Own Workshops. The charette will bring together eight PIE Network staff members who are experienced with both designing exhibits and making computational construction activities accessible for broad audiences. Staff will work in teams to build exhibit prototypes in the Exploratorium's Exhibit Shop and try out prototypes with visitors on the Exploratorium exhibit floor. These prototypes will be refined to produce the final exhibit elements.
- *"Invention at Play" Staff Workshop.* In fall 2002, the PIE Network will organize a workshop for staff members from the nine museums hosting the traveling *Invention at Play* exhibition. The workshop will provide training on the use of the PIE components within the staffed program space of the exhibition, and guidance on how to organize MindFest events and Make-Your-Own Workshops. The Lemelson Center will provide additional on-site training for each host museum. This model was used with great success with the traveling exhibition *Psychology: Understanding Ourselves, Understanding Each Other.*
- *MindFest Manual.* PIE Network staff will produce an illustrated MindFest Manual to be distributed to all museums on the *Invention at Play* national tour. The manual will be designed to help the museums' public program staff organize MindFest events at their own sites, adapted to local strengths and audiences. The manual will include sample program plans and materials lists for Construction Zones; ideas for Make-Your-Own Workshops; strategies for involving local inventors and artists; and contact information for experienced playful-invention presenters and workshop leaders from around the country.

3.4 The PIE Network. The PIE Network will be based on a close collaboration among MIT Media Lab and the PIE museums. A core group of Media Lab researchers (focusing on design of new technologies for learning and education) will work together with PIE museum educators and program developers throughout the project, sharing ideas, technologies, and support materials with one another. Media Lab researchers will work closely with museum staff to integrate new technologies and educational ideas into MindFest events and Make-Your-Own Workshops. Staff development and collegial support are an integral part of the PIE network concept. Educators and program developers from the museums will meet and communicate regularly to share project ideas, offer feedback, make presentations at one another's MindFest events, collaborate on development of materials, and learn from one another's experiences (see Project Organization section below).

4. Sample Scenario

"Look at that weird kite!" shouts Eddy, 9, as he walks towards the museum with his sister Celia, 12, and their mother. As they get closer, Celia notices a camera attached to a mechanical contraption hanging from the kite. "Why would anyone put a camera on a kite?" she asks.

As they enter the museum, they head toward the MindFest banner. Inside, they see a bustle of activity. They walk through exhibit tables displaying kinetic sculptures, whirligigs, robotic ants, and other colorful creations. They start to talk with a pair of college students who had built a machine that spits out melted chocolate to form 3-D objects. But then they realize it's almost starting time for the workshops they signed up for.

They check the MindFest map and agree to meet in the Construction Zone after their workshops. Celia heads off to a workshop called "Make-Your-Own Musical Instrument." The workshop leader, a local musician, starts by showing several examples of home-made instruments, including one that uses Play-Doh to create music. Celia likes that one best and tries it out. She rolls a ball of green Play-Doh on top of two metal contacts, changing the pitch and rhythm of the music as she molds the Play-Doh into different shapes. The workshop leader shows how the instrument works: a "cricket" computer detects the change in resistance through the Play-Doh and sends a signal to a small MIDI synthesizer. Celia starts to make her own Play-Doh instrument, controlling a flute sound. The woman sitting next to her makes a similar instrument, but controlling percussion sounds. The two of them decide to combine their projects, and they spend the rest of the workshop playing duets with two balls of Play-Doh.

Meanwhile, Eddy and his mother go to the "Make-Your-Own Sports Sensors" workshop. They learn how to use various sensors to make physiological measurements, such as heart rate, skin temperature, and perspiration level. Each person in the workshop chooses a sensor to put on, and the workshop leader shows them how to program their devices to record data every five seconds. Eddy and his mother both put on heart sensors and spend a few minutes figuring out how they work. Once they are sure that their sensors are collecting data, they walk around the museum for ten minutes. When they return, they upload their data to a computer. They are surprised to see that both of their heart rates increased sharply at about the same point in time. They wonder why: Did they get scared at some point? Then they realize that increase probably came when they walked up the stairs. Now Eddy wants to try again to see if he can get his heart rate to go really high by going up and down the stairs several times.

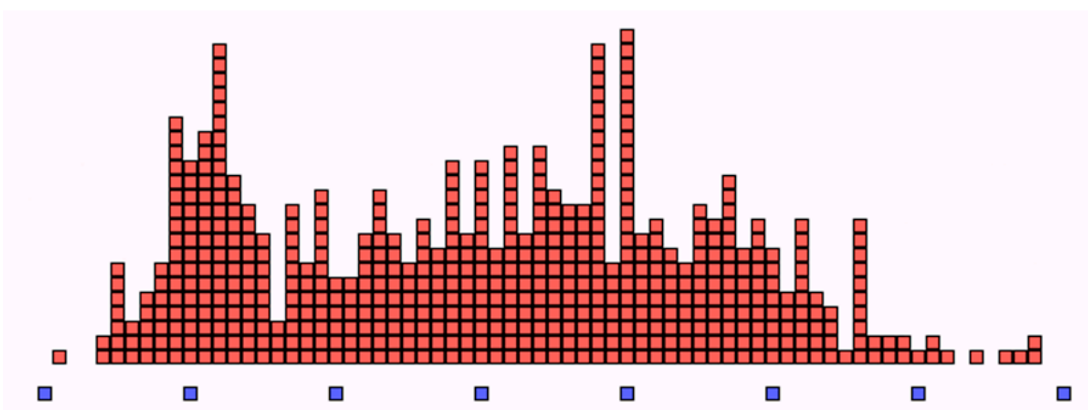
After the workshop, Eddy and his mother meet up with Celia in the Construction Zone, where they join a group of people working on a chain-reaction contraption: each person builds a device that triggers the next device in the sequence. While Eddy and Celia work on the project, their mother watches a video feed from the museum auditorium, where a panel of local artists and inventors are discussing "art and invention."

Before leaving MindFest, Eddy and Celia and their mother return to the Exhibit area to look again at the chocolate 3-D printer. Nearby is a display of photographs taken by a kite-camera, just like the one they saw earlier in the day. There are pictures of rivers, parks and a local playground, all taken from a bird's eye view. Their last stop is at a table where a graduate student is wearing a jean jacket with a sequence of animated patterns, thanks to tiny lights sewn into the fabric. The graduate student gives Celia and Eddy PIE Project Pamphlets, with ideas and plans for other "light-wear" projects.

A week later, at home, Celia and Eddy remember the light-wear idea, and decide to try to add lights to their Halloween costumes. Following suggestions from the PIE Project Pamphlets, they gather together some old holiday lights and some AA batteries. Eddy integrates lights into his Batman cape, while Celia makes a flashing necklace to add to her costume. One of the project pamphlets suggests ways to create animated patterns with the lights, with the use of programmable bricks, available at the museum's after-school space. Celia and Eddy ask their mother if they can go there sometime soon.

5. Audience

5.1 Who? The initial MIT MindFest event in 1999 was designed to include activities for both children and adults. The histogram below (with age 0 at the left and age 70 at the right) shows how the event did, indeed, attract participants of all ages. Thus, MindFest provided an opportunity, rare in society today, for people of different generations to work side-by-side (and often together) on projects, and for children to observe firsthand how people of different ages and levels of expertise come up with ideas and solve problems.



As with the first MindFest, the PIE Network is designed to draw together people of mixed ages and diverse backgrounds. Activities will be designed especially for ***families***, with a focus on families with children ages 9-14 (a major audience segment at the first MindFest). Previous outreach projects (e.g., the National Urban League Preschool Science Collaborative, NSF grant ESI-8851088) have shown the importance of providing opportunities for parents to collaborate with their children on open-ended science activities; through such activities, parents can gain a deeper appreciation for the value of science inquiry and explorations, and become more supportive of these types of activities at home. The PIE Network, through MindFests and Make-Your-Own Workshops, aims to encourage similar parent-child collaborations, to build support for playful invention activities as a gateway to science learning.

Invention and "tinkering" are typically viewed as the province of boys, and new PIE technologies (such as LEGO MindStorms) are most common in upper-income households. The PIE Network will make an explicit effort to make these technologies and activities accessible and appealing to a more diverse audience, aiming to bridge the gender and socio-economic gaps. PIE staff members will build on their own previous experience (e.g., Inquire Within, Smog Watch, Computer Clubhouse, Investigation Station, Science Zone) – and experience of others (e.g., Operation SMART, PISEC, Family Science) – in implementing programs designed to be inclusive of children, families, and communities who do not typically become involved in invention and inquiry activities.

Although the PIE Network will focus especially on parents and children, we expect that PIE activities, pamphlets, and online materials will also be of interest to educators, hobbyists, and other lifelong learners.

5.2 How Many? Some PIE activities, such as Make-Your-Own Workshops, will involve relatively small numbers of participants, reaching thousands of people over the course of the grant. But these activities are the ones most likely to result in transformative learning experiences for the individuals involved. Research studies have found that people, when engaged in personally-meaningful invention projects, are likely to develop a deep understanding of the mathematical and scientific concepts underlying the activities; gain an appreciation for interdisciplinary problem-solving approaches; and develop a greater sense of control (and responsibility) over the learning process (e.g., Harel and Papert, 1991).

Other PIE activities are designed to reach a much larger audience (millions of people), aiming to increase awareness of new research-based educational technologies and activities. The exhibit components designed for the staffed space within the Lemelson *Invention at Play* exhibit will reach roughly 1 million people during the first three years of the national tour of the exhibit. And, based on our previous experience with educational Web resources developed at the Exploratorium and Science Museum of Minnesota, we expect to get more than a million visits to the online PIE Idea Library over the course of the three-year grant.

6. Project Organization

6.1 PIE Museums. The six initial PIE museums – Science Museum of Minnesota, the Exploratorium, Lemelson Center at the Smithsonian, American Visionary Art Museum, Fort Worth Museum of Science and History, MIT Museum – were selected based on: commitment to the goals and spirit of the PIE Network; strong track record for educational program and materials development; commitment to integrate PIE activities into ongoing educational activities (and continue beyond the three-year grant period); ability to raise additional funds to support local activities; and geographic diversity.

The following descriptions of the PIE museums highlight how each museum will contribute to the PIE Network:

- *The Exploratorium*, founded in 1969, has been a pioneer and leader among interactive science centers. At least 90% of the nation's science museums, and 70% of the museums worldwide, have borrowed ideas from Exploratorium exhibits or programs. As part of the PIE initiative, the Exploratorium will expand the range of events and family workshops in its Production Studio, a multimedia laboratory designed to foster projects that combine computer, video, and audio technology with traditional tools and materials. The staff of the Production Studio will develop new PIE activities in close collaboration with the museum's nationally recognized artists-in-residence, Exploratorium educators, and exhibit developers. The Exploratorium will take the lead in staff development for the PIE Network, organizing a charette for staff from all PIE museums in 2002. The Exploratorium will also organize and facilitate a charette to develop components for the staffed program space in the *Invention at Play* exhibition.

- *Science Museum of Minnesota* recently moved into a $100 million, 400,000 sq. ft. new building on the banks of the Mississippi River in St. Paul. The museum's participation in the PIE Network will be spearheaded by its Learning Technologies Center, an applied research and development center focusing on the role of new technologies in science learning. The Learning Technologies Center has collaborated with the MIT Media Lab for the past five years, and it has been successful in designing workshops and classes (such as "Contraptions Collaborations") that use MIT technologies in ways that interest girls as well as boys. The museum has brought together art, science, and technology in its innovative Studio 3D after-school program, funded by the Department of Education's Community Technology Centers program. The museum will lead the development of the PIE Online Idea Library, building on its experience developing Web-based science-learning resources that encourage visitor contributions. The museum will organize the PIE Network's initial MindFest event and advisor meeting in spring 2001, and it will host sessions highlighting the developments of the PIE Network at the ASTC conference in 2003.

- *American Visionary Art Museum (AVAM)*, located in Baltimore's Inner Harbor, is dedicated to the study, collection, and exhibition of visionary art – that is, art and invention produced by self-taught individuals. The PIE initiative fits naturally into the museum's plans to open the *Thou Art Creative Center*, a new participatory space which will allow students, teachers, families, seniors, and other visitors to creatively respond to their AVAM visits through hands-on art and playful-invention activities of their own. The museum will host a MindFest event in conjunction with the opening of the new center in 2003. The museum will bring not only a sense of aesthetics but also a sense of humor to PIE activities. It will integrate MIT technologies into successful annual events like the Kinetic Sculpture Race, and also into smaller, more frequently-held family workshops that support its educational mission to uncover and empower ordinary (actually extraordinary) tinkerers, artists, and inventors of all ages.

- *Fort Worth Museum of Science and History* is North Texas's most popular cultural attraction, attracting more than 1.3 million visitors each year. The museum has a long tradition of hosting large-scale public events to engage families in hands-on science activities; in recent years, it has organized major events during National Science and Technology Week and National Engineers Week, in partnership with major science and technology companies, including Radio Shack, Lockheed Martin, IBM, and Intel. The museum will build on this tradition by hosting two MindFest events during the next three years. As part of the PIE initiative, the museum will pay special attention to partnerships with schools and teachers, drawing on its expertise in making connections between formal and informal education. The museum will integrate PIE activities into its ongoing Hands On Science partnerships with five local school districts. The museum will also develop a one-week class featuring PIE activities for 9-10 year olds at its Museum School, located within the museum building. The museum sees the PIE initiative as an opportunity to extend its expertise in science learning to the digital realm, exploring how to integrate new technologies into inquiry-based activities.

- *The Lemelson Center for the Study of Invention and Innovation*, located in the Smithsonian Institution's National Museum of American History, is dedicated to documenting, interpreting, and disseminating information about invention and innovation, encouraging inventive creativity in young people, and fostering an appreciation for the central role invention and innovation play in the history of the United States. The Lemelson Center will work with other PIE museums to develop a staffed program space within its *Invention at Play* exhibition, drawing on ideas and incorporating technologies from MindFests and Make-Your-Own Workshops. In fall 2002, the Lemelson Center will host a month-long series of MindFest programs, designed especially to serve families in the local Washington DC area. Over the years, the Lemelson Center has highlighted the lives and works of inventors from many different backgrounds, and it will draw on this experience to help other PIE museums make connections to non-stereotypical inventors.
- *The MIT Museum* is a small university museum, aiming to "nurture and provide opportunities for innovation, invention, and experimentation, in keeping with the spirit of the Institute." Founded in 1971, the museum is especially focused on the use of science and technology for artistic expression. As part of the PIE initiative, the MIT Museum plans to expand its successful series of Family Adventures in Science and Technology public programs, which offer activities to engage family groups in explorations of current science and technology research topics and to encourage conversation with the MIT community. The museum will also incorporate PIE-related activities into its new Discovery Space, a staffed exhibit space designed to inspire creativity and inventive thinking. The museum has special interest in expanding socio-economic diversity of its family program participants; as part of its PIE efforts, it plans to work with underserved communities not only in inner-city Boston but also in rural southern Maine. To help disseminate PIE ideas, the museum will explore ways to help small science and children's museums in New England initiate PIE-style activities.

6.2 MIT Media Laboratory. Since opening its doors in 1985, the MIT Media Lab has established itself as an international leader in the design and study of innovative digital technologies. In particular, the Media Lab has developed educational technologies used by millions of children around the world, and has organized educational projects involving children from diverse economic and cultural backgrounds. The Media Lab will participate in the PIE Network in several ways: sharing the knowledge it gained from organizing the first MindFest; providing innovative technologies to be used at museum-based MindFests; running Make-Your-Own Workshops and participating in panel discussions at MindFests; developing new Make-Your-Own Workshops; helping the museums develop new Make-Your-Own Workshops; working with the museums to test out prototype technologies (such as new sensors or new generations of programmable bricks) developed at the Media Lab. From these interactions, the Media Lab hopes to gain feedback that will help guide the development of future technologies and activities.

6.3 The PIE Network. Collaborations can be difficult. But the PIE Network starts with a solid foundation. The Principal Investigators, though based at three different organizations, have worked together intensively on several previous education and research projects. And each of the PIE museums has had some experience working with at least one of the other participating organizations.

Face-to-face meetings will play an important role in building community among the PIE organizations. Staff members from all PIE organizations will gather together at least once a year for staff development and collaborative activities. Even before the official start of the project, staff members from all museums (providing their own transportation) will come to MIT this August for a five-day hands-on workshop, at which they will gain experience with new MIT technologies and share initial ideas for Make-Your-Own Workshops. With NSF support, future "all PIE" gatherings will include participation in: (a) the first MindFest at Science Museum of Minnesota in spring 2001, where PIE staff will lead workshops and join a post-MindFest critique to develop ideas for improving future MindFests; (b) a PIE staff-development charette organized by the Exploratorium; (c) an idea-exchange session linked to the Lemelson Center's month-long MindFest in 2002; (d) a session at the ASTC annual meeting in fall 2003.

These meetings will form the foundation for continuing communications and follow-up visits among PIE sites. MIT Media Lab staff (including Bakhtiar Mikhak, Mitchel Resnick, and Diane Willow) and key PIE Network staff (including Mike Petrich, Natalie Rusk, and Karen Wilkinson) will visit PIE museums to collaborate on activity development, documentation, and materials development.

MIT Media Lab, Science Museum of Minnesota, and the Exploratorium will divide responsibilities for coordination and logistics of the PIE Network, with the Media Lab coordinating with MIT Museum, Science Museum of Minnesota with the Lemelson Center, and the Exploratorium with Fort Worth and American Visionary Art Museum.

6.4 Advisory Board. The PIE Network Advisory Board will bring together innovators in the fields of science, art, engineering, and education to guide the development of the PIE Network activities:

- *Sarah Alexander and Sue Jackson*, the creators of Cabaret Mechanical Theatre, a London-based museum featuring whimsical automata and other mechanical sculptures
- *Hubert Dyasi*, Professor of Science Education at City College of New York, a leading expert in inquiry learning and teacher professional development
- *Mike Eisenberg*, a computer scientist at University of Colorado, whose research focuses on the creative integration of the physical and digital worlds (as in his Hypergami project)
- *Yolanda George*, Deputy Director of Education and Human Resources Programs at American Association for the Advancement of Science (AAAS), who has led science-education outreach initiatives involving community organizations that serve girls, minorities, and children with disabilities.
- *Ned Kahn*, an internationally-recognized artist and developer of highly-acclaimed interactive science exhibits featuring explorations of weather and other natural phenomena.

The Advisory Board will meet together with PIE staff twice during the three-year grant, once in connection with a MindFest event and once in connection with a staff-development workshop. The advisors have also agreed to consult informally with MIT researchers and PIE museum staff throughout the course of the project.

7. Sustainability

This three-year grant will provide a foundation for a set of sustainable activities related to Playful Invention and Exploration.

- PIE Museums will incorporate Make-Your-Own Workshops into their ongoing public programs. For example, the workshops will become part of the Youth and Family camps and classes at Science Museum of Minnesota; the Family Adventures in Science and Technology activities at the MIT Museum; and Production Studio offerings at the Exploratorium.

- Corporate sponsors of the MIT Media Lab provided financial support for the initial MindFest at MIT in 1999. Once MindFest events become established at museums (with NSF support), we expect strong interest from corporate sponsors to support, promote, and expand these efforts.

- Resources developed through this grant (including PIE Project Pamphlets, PIE Idea Library, and MindFest Manual) will be available online for use by other museums and organizations, enabling them to organize their own PIE events and activities and make use of programmable bricks and other computerized construction kits. PIE staff will act as informal advisors to other museums and organizations in their regions, supporting the growth of the PIE community.

- The PIE Network will draw on lessons learned from the Computer Clubhouse project (Resnick, Rusk, and Cooke, 1998), a network of after-school learning centers for inner-city youth, co-founded by two of the Principal Investigators in 1993. The Clubhouse Network has succeeded in attracting ongoing corporate support; earlier this year, Intel Corp. committed $20 million to support the opening of 100 new Clubhouses over the next five years.

8. Evaluation

The Center for Children and Technology (CCT), a division of Education Development Center, is a leader in the evaluation of educational research and dissemination efforts, with extensive experience working with informal-learning organizations. CCT will work closely with the PIE project partners to develop an embedded evaluation that helps participants, project staff, and a larger public audience of parents, community-based organizations, community foundations, and businesses share questions, examples, and practices that emerge from the project. While the data gathered will be used for formative purposes during the implementation of the project, this information will also be used in a summative evaluation of the project and its impact.

The evaluation process will use three overlapping strands to inform both the formative and the summative aspects of this evaluation. The first component of the work will look at the iterative design processes used among the partners to hone the Make-Your-Own Workshops and the Mindfests. It will focus on what it takes to develop and implement these processes at partner institutions – and how the network can develop collegial support for improving the museums' effectiveness in fostering attitudes and understandings of scientific and engineering ideas. This work will be focused on creating information useful in producing the PIE Project Pamphlets, the MindFest Manual, and components for the *Invention at Play* exhibit.

The second strand of the evaluation will look at the actual artifacts produced by participants and will develop discussion rubrics. These rubrics will guide both participants and observers in the analysis of the science and engineering concepts, without compromising the playful nature of the inquiry that is being fostered. The rubrics will be developed through interviews and group reflections on the work, and then used both online and in-person to leverage the experience as both a designer and a observer of the designs. The format of these rubrics will be templates and concept diagrams that participants complete as an accompaniment to images and descriptions of their work. This strand has as an explicit objective the creation of conversations and analysis of the inventions that will provide tangible evidence of the project's impact.

The third component, which will form the core of the summative analysis, will document the benefits that derive from varying degrees of participation. We will look at how various age levels are engaged in, and affected by, various aspects of the project. We will also look at the impact the project has on participating institutions.

In addition to participation in regular meetings of the project staff, advisory board meetings, and observation at individual museum offerings, CCT will provide a yearly methodology plan for project review. This is critical since some of the evaluation activities require incorporation into the programmatic activities. We will also issue an interim report prior to the second advisory committee meeting and a final report in both print and interactive online format for use in the dissemination process.

9. Work Plan

Year One: Initial Prototyping and Review		
2001	Winter	• Prepare and distribute research technologies to PIE museums (MIT) • Review evaluation methodology plan for Year 1 (CCT with all) • Prototype initial Make-Your-Own Workshops (All) • Plan first PIE MindFest (SMM with MIT, Exploratorium)
	Spring	• Advisory board meeting at SMM (MIT with all) • Implement, document, and review of first MindFest and Make-Your-Own Workshops at Science Museum of Minnesota (All) • Interviews with participating families at SMM MindFest (CCT) • Exhibit charette at Exploratorium to develop prototypes for *Invention at Play* exhibition (Exploratorium with Lemelson, MIT, SMM, Fort Worth, ASTC)
	Summer	• Follow-up at Lemelson of revised prototypes before exhibit production (Lemelson, Exploratorium, MIT, SMM) • Refine and test Make-Your-Own workshops at each museum • Create discussion rubric based on initial interviews of participants (CCT) • Initial design of PIE Online Idea Library (SMM with CCT, others) • Initial design of PIE Pamphlet template (MIT with others)
	Fall	• Review and revise design of PIE Online Idea Library and PIE Pamphlet (All) • Review evaluation methodology plan for Year 2 (CCT with all)

Year Two: Development and Revision		
2002	Winter	• Interim evaluation report (CCT) • PIE staff development charette at Exploratorium (Exploratorium, CCT, All) • Advisory board meeting at Exploratorium • Review and debug PIE Online Idea Library prototype (SMM with CCT, all) • Revise and develop Make-Your-Own Workshops (All)
	Spring	• Draft first PIE Pamphlets and contribute to PIE Idea Library (All) • MindFest at Fort Worth during National Science and Technology Week • Draft MindFest Manual (MIT, SMM with all)
	Summer	• Launch PIE Idea Library for public use and contributions (SMM) • *Invention at Play* exhibit opens with PIE program space (Lemelson)
	Fall	• Distribute first set of PIE Pamphlets (All) • Complete MindFest Manual (MIT, SMM with Lemelson)

	• MindFest month at National Museum of American History (All) • Staff training workshop for *Invention at Play* museums (Lemelson, MIT) • Review evaluation methodology plan for Year 3 (CCT with all)
Year Three: Integration and Dissemination	
2003 Winter	• MIT Museum MindFest (MIT Museum with MIT, Exploratorium) • Integration of Make-Your-Own Workshops into museum programs
Spring	• Revise and distribute second set of PIE Pamphlets (All) • Revise PIE Idea Library Web site based on evaluation results (SMM, CCT) • Second MindFest at Fort Worth (Fort Worth with Exploratorium, MIT)
Summer	• MindFest at American Visionary Art Museum (AVAM, MIT, Explo.) • Develop and distribute third set of PIE Pamphlets (All)
Fall	• Sessions on PIE Network activities and results at ASTC Conference (All) • Complete final report for NSF and publish online (CCT, MIT, SMM)

10. Key PIE Network Staff

Mitchel Resnick, associate professor at the MIT Media Laboratory, specializes in the development and study of computational tools that help children learn new things in new ways. Resnick led the development of the ideas and technologies underlying the LEGO MindStorms robotics construction kit. He has also led the development of StarLogo software and the Virtual Fishtank museum exhibit, designed to help people learn about complex systems. Resnick was awarded a National Science Foundation Young Investigator Award in 1993. Resnick will serve as Project Director of the PIE Network, and will supervise PIE activities at the MIT Media Lab.

Natalie Rusk, Learning Technologies Fellow at the Science Museum of Minnesota (SMM), guides the development of new applications of digital technology in museum programs. She is overseeing the technical and educational aspects of development of the Web site and classroom activities for the museum's NSF ISE grant *Window on Catalhoyuk*, and led SMM's development of *Thinking Fountain* and other Web resources in the Science Learning Network. With Resnick, she co-founded the Computer Clubhouse, an after-school learning program for inner-city youth. Rusk will serve as a Project Director of the PIE Network, coordinating interactions among all partners in the network, and she will oversee the development of the online PIE Idea Library.

Karen Wilkinson and **Mike Petrich** apply their backgrounds as fine artists and curriculum developers to the design and integration of educational technologies at the Exploratorium. They developed the *Science Zone*, an informal learning environment at the Museum Magnet School in St. Paul, MN; *Investigation Station*, an after-school program in Landfall, MN; and a series of inquiry-based exhibits at the Science Center of Eastern Connecticut. They have created several Internet-based science resources, including the *Thinking Fountain* and *Windmills and Whirligigs* at Science Museum of Minnesota, and participated in the development of the NSF-funded *Beyond Black Boxes* project at the MIT Media Lab. Wilkinson and Petrich will serve as Program Directors at the Exploratorium, and will lead the exhibit charette and staff-development charette.

Diane Willow has 25 years of experience as an exhibition and program developer at The Children's Museum, Boston, where she developed materials, media, exhibitions, public programs and curriculum for children and youth, parents, teachers and community educators. She has been responsible for the concept development and implementation of model projects focusing on children's experience of the urban environment as a domain for creative inquiry and expression. Since September 1999, she has had an appointment at MIT as Artist-in-Residence, and played an important role in the organization of MIT's MindFest.. In the PIE project, Diane will serve as Network Director, and guide development of new Make-Your-Own Workshops, MindFests, PIE pamphlets, MindFest Manual, and exhibit components.

Bakhtiar Mikhak is a research scientist at the MIT Media Lab. His research interests include developing new programming environments and computational construction kits for science and engineering education. For the past three years, he has worked closely with educators and children in classroom and after-school settings. Mikhak received his BA in physics from the University of California, Berkeley (1988) and MS and PhD degrees from the University of California, Los Angeles (1989, 1995). He will serve as Technical Director of the PIE Network.

Brian Smith is assistant professor at the MIT Media Lab and head of the Lab's Explanation Architecture research group. He received his BS in computer science from UCLA (1991) and his PhD in learning sciences from Northwestern University (1998). As part of the PIE initiative, he will develop new design activities that integrate computation with static and moving images.