Rethinking Robotics: Engaging Girls in Creative Engineering

A Proposal to National Science Foundation, Informal Science Education Program
December 2005

PROJECT DESCRIPTION

INTRODUCTION

Every January, during intersession between semesters, teams of MIT students participate in a robot design competition. Students work for four weeks – often working around the clock, with little sleep – to design, build, and program robots to compete against one another in a specified task. Hundreds of spectators pack into the largest auditorium on campus to watch the finals of the competition in late January.

In 1996, two Wellesley College professors decided to organize a similar event at Wellesley, an all-women liberal-arts college just outside Boston. The two Wellesley professors were impressed with what MIT students learned through the process of building and programming robots, and they wanted their students to have a similar experience, but they didn't feel that a robot competition would attract the same level of interest among Wellesley students. They noted that fewer than 20% of the students participating in the MIT competitions were women, even though the MIT student body had more than 40% women. For robotics activities to succeed at Wellesley, a different approach was needed. So the Wellesley professors organized a course called *Robotic Design Studio*. Like the MIT robot competition, the Robotic Design Studio was a month-long immersive experience, and participating students used the same robotics technology. But instead of creating robots for a competition, the Wellesley students built a diverse collection of artistic and expressive creations, such as a robotic flower that closed its petals when an insect approached. At the end of the month, instead of a competition, there was an exhibition of the students' robotic inventions – much like the opening of a new installation at an art gallery.

The Wellesley Robotic Design Studio had a very different feel from the MIT robot competition. But the results were similar: Wellesley students learned the same engineering ideas and concepts as their MIT counterparts, and the Robotic Design Studio became one of the most popular events on campus.

Just as the Wellesley Robotic Design Studio has provided an alternative pathway for college students to use robotics technology and learn engineering concepts, alternative pathways are also needed for pre-college students. In recent years, robot competitions have become increasingly popular among pre-college students. For example, the FIRST LEGO League robot competition, open to students ages 9-14, grew from 200 student teams in the US in 1998 to 4100 student teams in the US in 2004 (and more than 2000 student teams elsewhere in the world). But as with the MIT robot competition, there is a gender imbalance: only 30% of the FIRST LEGO League participants are girls.

1. INNOVATION

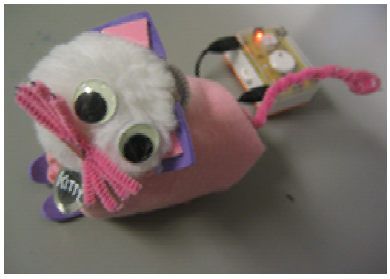
1.1 Project Deliverables

We propose to develop the ideas, infrastructure, and support for a new genre of robotics activities, designed as an alternative to robotics competitions, in an effort to engage more girls in creative-engineering activities in after-school settings. We will work with after-school centers and community organizations to establish ***Cricket Craft Clubs***, in which girls ages 9-12 will work on projects integrating art and engineering (such as musical sculptures or painting machines), in the spirit of the Wellesley Robotic Design Studio. Participants will work on their projects over a period of ten weeks, leading to a culminating Cricket Craft Exhibition at which they display their robotic creations for family and friends.

Robot competitions such as First LEGO League and Botball have grown to an impressive scale and introduced huge numbers of young people to the ideas, joys, and challenges of engineering. We believe that Cricket Craft Clubs have the potential to achieve similar success, providing a new entry path into

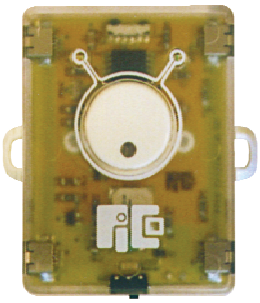
engineering for a diverse audience of young people in community centers and other informal-learning settings.

In the Cricket Craft Clubs, participants will use the Cricket technology that our research team has developed over the past decade with funding from NSF research grants. The Cricket is a tiny programmable device that children can embed in their physical creations. Children can connect sensors (such as light sensors, touch sensors, and sound sensors) and output devices (such as motors, colored lights, and music-making devices) to the Cricket, then write simple computer programs to tell the Cricket how to behave. For example, a girl might create a cat using craft materials, then add a light sensor and a sound-making device. She could write a program (using the Cricket's easy-to-use graphical programming language) that waits for the light sensor to detect someone "petting" the cat, and then tells the sound device to play a meowing sound.



Although the activities might seem different on the surface, programming a cat to meow when you pet it is actually quite similar to programming a robot to react to an obstacle, in terms of underlying computer-science concepts. For example, to tell a robot to change direction when it hits the wall, a program could wait until the touch sensor is pressed, then tell the motors to reverse direction. The program for the cat waits until the light sensor detects low light, then tells the sound box to play a sound. The programming skills and concepts are the same, only the context is different.

Until now, Crickets with the capability to control lights and music have been available only as research prototypes, for use by MIT Media Lab partners (such as museums participating in the NSF-funded PIE Network). But beginning in January 2006, Cricket technologies will begin to be sold as a product by a small company (Playful Invention Company), making them available to a much larger audience.



Cricket

Cricket actuators:
multi-colored light, sound box, numerical display, motor

Cricket sensors:
light sensor, touch sensor, sound sensor, resistance sensor

The Crickets are similar to the RCX technology that underlies the LEGO Mindstorms robotics product, but the RCX focuses on controlling motors while Crickets also allow for more expressive output (with colored lights, music, and sound). So while LEGO Mindstorms is ideally suited for robot competitions, Crickets are ideally suited for the artistic creations at the heart of Cricket Craft Clubs.

We recognize that access to technology alone is not enough (Resnick, Rusk, and Cooke, 1996; Center for Children and Technology, 2005). Additional support is needed to ensure young people will learn to use this new technology in creative and meaningful ways. This grant will create the infrastructure needed to establish and support Cricket Craft activities in after-school programs, as described below.

Cricket Craft support materials. We will develop a collection of online materials to support after-school centers in organizing Cricket Craft Clubs. These support materials will include:

- **a Cricket Craft Club video** that provides an overview of the activities and shows Cricket Craft Clubs in action (available on DVD as well as online for download)
- **a week-by-week guide** outlining the process for running a 10-session Cricket Craft Club, from setup to final exhibition
- **illustrated instructions** on how to get started with Crickets
- **mentor materials** for supporting the involvement of volunteer mentors
- **related resources** that offer links to relevant articles, further activities, and pathways for pursuing creative engineering from school to career.

Semi-annual themes. Twice each year, we will announce a new theme as a focus for activities at Cricket Craft Clubs. We will aim to find themes that strike a balance between being broad enough to give everyone freedom to work on a project that connects with their interests, and specific enough to foster a sense of direction and common experience. For example a theme one season might be *Music Makers*, where Club members use Crickets to invent new kinds of programmable musical instruments. Other possible themes include *Interactive Jewelry* – designing different kinds of wearable art, and *Storybook Scenes* – using Cricket creations to tell a story. By working on the same theme at the same time, youth and staff at different Cricket Craft Clubs will be able to share ideas and learn from one another.

To introduce each new theme, we will create a brief yet compelling **project theme video** designed to provide ideas and inspiration for theme-related projects. We will also provide illustrated instructions for creating two or three **sample projects** based on the theme, highlighting core engineering, design, and programming concepts. Both the project theme video and sample projects will be designed to be generative in order to encourage a wide variety of projects.

Structures for sharing. We will develop an **online exhibition gallery** for participants across the country to share their Cricket Craft projects. Along with allowing uploading descriptions and photographs of their projects, the online form will ask interview questions that encourage girls to reflect on their process for creating the project, including what was most difficult and what they like best about what they made. The online gallery will offer participants a way to share what they have made, provide a record of their work for future reference, suggest ideas for new projects, and give a sense of a larger community.

In order to further support girls in reflecting on their process and encourage sharing across sites, we will create a Cricket Craft Club blog that allows each Cricket Craft Club to post an entry describing what they worked on each week. The blog entry form will be structured with inviting prompts designed to focus attention on specific aspects of their experiences, including ideas generated, challenges encountered, and problem-solving approaches used in order to address challenges. We will also provide a support discussion area for staff, mentors, and interested youth to ask questions, exchange tips, and offer suggestions.

These online components will be designed, tested, and revised, based on our extensive experience developing online mechanisms for young people to share their projects and ideas. Together these structures for sharing will encourage reflection and provide a wider community for inspiration and recognition.

Staff workshops. The collection of Cricket Craft online resources will provide all the background and support materials needed for any interested educator, parent, or other after-school program leader to

launch and implement a Cricket Craft Club. However, in order to ensure that the initiative reaches young people in low-income neighborhoods, we are partnering with two leading after-school organizations—the Boys and Girls Clubs of America (BGCA) and the Intel Computer Clubhouse Network—to provide a series of local, regional, and national workshops for their staff to become inspired and ready to initiate Cricket Craft activities at their sites.

The workshops will draw on the co-PIs' extensive experience developing and leading workshops on creative use of new technologies for educators in after-school centers, museums, and other informal learning environments. These workshops will provide staff members with a hands-on introduction to Cricket technology and to the core ideas underlying the Cricket Craft Clubs.

During Year 1, we will offer an initial two-day workshop for staff from six Boston-area after-school programs (including a combination of four Boys and Girls Clubs and Computer Clubhouses), which will serve as pilot sites as we develop materials for broader dissemination. In Year 2, we will expand to offer one-day Cricket Craft workshops for BGCA and Computer Clubhouse staff in three regions of the country (to be determined in collaboration with BGCA and Computer Clubhouse Network). In each of the three regions, there will be five "lead outreach" sites, for a total of 15 sites nationally. We will maintain contact with these sites, providing support and soliciting feedback, through a combination of monthly conference calls and ongoing email contact.

Beginning in the spring of Year 2, we will begin a broader dissemination through the Boys and Girls Clubs of America and Computer Clubhouse Network by offering workshops for staff at the BGCA National Educational Technology conference and the Computer Clubhouse Network annual conference. In Year 3, we will expand to reach staff at regional BGCA Youth Development Conferences and regional Computer Clubhouse conferences.

Extensions to the Cricket technology. We will develop prototype extensions to the Cricket technology and test them at selected after-school centers. For example, we will develop a sound-recorder device so that youth can add their own voices (or other sounds from the environment) to their Cricket creations. We will also work on developing a motion sensor to allow the creation of Cricket Craft projects that respond to people's movements. These extensions will be designed to expand the range of Cricket Craft projects possible, increasing possibilities for engagement and for learning.

1.1.1 Example Scenario

Anna and Chikoti are regular visitors to a Boys and Girls Club in Boston. Anna has been learning to play the piano; Chikoti enjoys drawing and doing various craft activities. They both enjoy using the computers at the Club to surf the Web, but neither has ever written a computer program.

They sign up for the upcoming Cricket Craft Club, which is scheduled to meet ten Monday afternoons over the next three months. When Anna and Chikoti arrive on the first day, along with a dozen other girls, they are immediately attracted by the diverse assortment of materials on the big table in the center of the room: colored pipe cleaners, cotton pompoms, plastic cups, different kinds of fabrics, LEGO motors, and a collection of unfamiliar electronic devices in translucent casings.

Claire, the Club coordinator, explains that they'll be using these materials to work on projects around the theme of "birthday celebrations." She shows a video with lots of examples, such as a machine that throws confetti, and party hats that light up when they get near each other. Claire introduces the girls to the Cricket and other electronic parts, and demonstrates how to program them from the computer.

Anna and Chikoti start by plugging a light into the Cricket and try programming it for the first time. They decide they want it to start light blue, then change to yellow. They are excited when they get it to work, and try placing the lights in frosted cups and seeing how they glow. They ask how they can add sound, and have fun experimenting with different sounds to go with the lights.

The next week, Anna and Chikoti decide they want to turn their lights into candles for a birthday cake. Over the next few weeks, they spend time building and programming their cake. Chikoti works on building a multi-layered cake out of cardboard and felt. For candles, she uses translucent straws slipped over colored lights. Anna works on writing the Happy Birthday tune, using the melody editor in the Cricket software. Each week, the coordinator shows them a new feature they can try. The girls learn how to use sensors, and choose a sound sensor to trigger their program: when someone tries to blow out the candles, the sensor will detect the sound. They put together a stack of programming blocks that turns on the lights (candles), waits for a loud sound, then turns off the lights and plays the birthday melody.

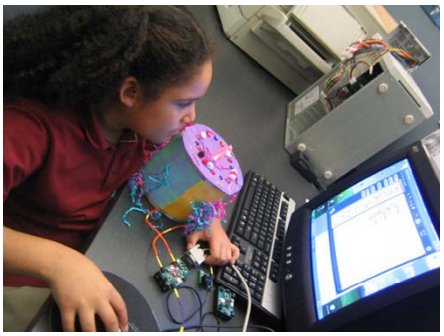
By week 9, the girls are ready to add their creations to the Cricket Craft Club online gallery. Anna and Chikoti learn how to upload a photo of their cake and a copy of the program to the website. Then they type in a brief description of their project, including how they got the idea, the biggest challenge they encountered, and the feature they like best.

Anna and Chikoti are excited to show off their project in the Cricket Craft Exhibition the following week. Lots of other kids from the Boys and Girls Club come to the exhibition, as well as other interested staff from around the club. Some parents and younger siblings also come inside to see. Anna and Chikoti's cake is placed on the dessert table, right next to a real cake.

1.1.2 Proof of Concept

To assess the potential for engagement of Cricket Craft activities, we tried out sample Cricket Craft activities over 10 weeks this fall (September-December 2005) with a group of 15 girls, ages 9-12, at one of the Boys and Girls Clubs of Boston.

Experimenting with sensors and lights



Programming music for a craft creation

We informally assessed the following aspects of the Cricket Craft Club activities.

- **Initial engagement:** From the first day, the girls became engaged in learning to program the colored lights on the Crickets and excited about incorporating craft materials (such as aluminum foil and frosted plastic cups) to reflect and diffuse the light.
- **Themes:** We tried out two different themes: birthday surprises and Halloween. Both inspired girls to generate many ideas and to chose a project they wanted to pursue. The girls split into pairs (without prompting), and continued to work in pairs on their projects.
- **Sustaining Interest**: One of our main questions was whether the high level of initial enthusiasm would be sustainable over the course of many weeks. We found that the girls were inspired to continue working together on their project ideas, and were motivated to complete their projects in order to show them at an exhibition for other friends and staff at the Boys and Girls Club.
- **Target audience**: The combination of Crickets and crafts engaged girls throughout the target age range of 9 to 12. The 12-year-olds in the group were more ambitious in building and learned more advanced programming concepts, including conditional (*if-then-else*) statements.

- **Mentoring:** Girls often asked for help on how to problem-solve both craft and programming issues, emphasizing the importance of having one or more mentors available, particularly in the initial sessions as they are planning their projects and learning how to work with sensors and actuators.
- **Previous familiarity**: Girls were asked, "Have you ever done any activities like working with these Crickets?" All the girls responded no. They saw building and programming with the Cricket as different from other computer and craft activities they had previously experienced.

This informal assessment has convinced us of the potential of Cricket Crafts to engage the target audience of girls ages 9-12 in after-school centers. However, much more work needs to be done. The funding for this project will allow the development of support infrastructure needed to enable other educators and youth program leaders to begin offering Cricket Crafts across the country.

1.2 Project Design

The following timeline summarizes the milestones over the course of the three-year project.

Year One: Initial Development, Prototyping, and Formative Evaluation

- Workshop for staff from Boston-area pilot sites
- Work with evaluator on formative evaluation process
- Initial theme and materials prototyped at Cricket Craft Club pilot sites
- New Cricket peripherals prototyped and tested
- Refinement of materials based on formative evaluation and other feedback from staff participants

Year Two: Launch Website, Support Materials, and Workshops for Early Adopters

- Begin distribution of Cricket Craft support materials for use by lead outreach sites and other early adopters
- Design and launch website to support activities at Cricket Craft Clubs
- Organize and offer workshops for staff at lead outreach sites in Boys and Girls Clubs and Clubhouses (a total of 15 additional sites in three metro regions)
- Organize and offer first round of workshops at national Boys and Girls Club and Clubhouse conferences
- Refine and update materials based on feedback and formative evaluation

Year Three: Broader Dissemination of Materials, Approach, and Findings

- Broaden dissemination of Cricket Craft support materials, to reach more after-school centers
- Introduce two new activity themes over course of the year
- Offer additional workshops at national and regional conferences for Boys and Girls Clubs and Computer Clubhouses
- Work with evaluation staff to complete summative and process evaluation
- Disseminate project findings at ASTC, NECC, and CTCNet conferences for researchers and practitioners
- Maintain website to ensure ongoing support, communication, and dissemination

1.3 STEM Content

The essence of engineering is imagining something, designing it, building it, and getting it to work. The projects we imagine for the Cricket Craft Clubs will provide a rich and accessible context in which to experience this process. By linking engineering to other disciplines (such as art and music), these

activities will provide a new entry point into engineering, enabling participants to engage with many of the "big ideas" of engineering in a very natural way. While working on their projects, we expect that participants will gain an appreciation and understanding for the following concepts that have been consistently highlighted in compilations of STEM standards for our target age group (e.g., American Association of Science, 1993; Computer Science and Telecommunications Board, 1999; International Technology Education Association, 2000).

Content related to the *process* of engineering and design:

- **The value of iterative design.** In the course of their projects, we expect that participants in Cricket Craft Clubs will learn that engineering is an iterative process in which they continually implement, test, debug, and refine designs. This process stands in stark contrast to many traditional "science experiments," where students (unlike practicing scientists and engineers) rarely have a chance to iterate on their designs.
- **General problem-solving strategies.** As participants work on Cricket Craft projects, they will learn how to break down big problems into smaller, more manageable parts, and they will develop the skills necessary to track down causes of failures. In our experience, the personal investment that young people typically have in these kinds of projects is critical to providing the motivation to persist despite setbacks, challenges, and frustrations.
- **Dealing with real-world constraints and tradeoffs.** Engineering is something that takes place in the real world, not in a textbook. The kinds of projects we are proposing serve to illustrate that the real world tends to be much messier and unpredictable than the idealized view that often dominates textbooks. Among the real-world lessons that participants will learn: some designs are impossible; solving one problem may create other problems; materials may limit what is possible; and some designs that are possible may not necessarily be desirable aesthetically.
- **Design in multiple domains.** A key challenge of engineering is that it often involves the design of systems with interacting parts, many of which may be quite different in character. The kinds of projects we are proposing naturally lend themselves to designing in multiple domains, since these projects typically have mechanical, computational, and artistic components.

Content related to specific STEM *concepts*:

- **Engineering concepts.** Cricket Craft Club activities will provide a motivating context for participants to learn specific engineering concepts related to sensing, control, and feedback. For example, participants might build a "smart house" that turns on the lights when it gets dark outside or a kinetic sculpture that spins faster the louder you speak.
- **Computer science concepts.** These projects will provide a good setting for youth to learn key computer science concepts, as well as strategies for writing and debugging computer programs. For example, we have found that writing programs to control objects in the physical world provides a particularly concrete and accessible way for people to learn ideas surrounding the flow of control in computer programs.

1.4 Addressing Project Risks

Cost of Programmable Devices: The cost of the Cricket technology could be a barrier to participation, particularly in low-income communities. We will provide Cricket kits free of charge to the six pilot sites and to the 15 additional lead outreach sites (based on need and potential impact). We are also pursuing grants from other foundations and sponsors to supply Cricket kits to other after-school sites.

Attracting Girls without Stereotyping: In our effort to attract broader participation by girls, we will need to be careful not to fall into gender stereotypes. We will work closely with our partners, advisors, evaluators, and participants to make sure we avoid the "pink software trap" (as described in the AAUW report, 2000) and ensure recognition of the broad diversity of interests among both girls and boys.

Need for Mentoring: We recognize that after-school center youth and staff will need mentoring to support their participation in the project activities. We will work with after-school centers to help them attract and develop mentors to provide ongoing support for the initiative. We will also provide support materials for recruiting and retaining mentors, based on our experience over the past 12 years involving mentors in the Computer Clubhouse programs.

Sustainability - The biggest factor that will contribute to maintaining the long-term interest of the Club members is the compelling and open-ended nature of the activities, which we believe will lead members to return for future Club cycles. A core design principle of the Cricket activities has been "Low Floor, High Ceiling" – we have tried to make the barriers for entry as low as possible, while retaining the ability to support much more sophisticated projects. Indeed, the Cricket technology is, in fact, quite similar to the technology used in university-level courses such as Wellesley's Robotic Design Studio or MIT's 6.270.

As far as the sustainability of the Cricket Craft Club program, we look to the model provided by organizations such as FIRST LEGO League and the KISS Institute's Botball. Both of these organizations have successfully maintained a nationwide network of competitive robotics activities by charging modest fees to support a small central staff, while relying on local organizations to generate funds to support their involvement over time (Melchior, 2005).

1.5 Educational Research and Prior Work

1.5.1 Research Basis for Cricket Crafts Approach

The Cricket Craft initiative is based on research on design-based learning, robotics in education, and gender-equity in computer science and engineering.

Over the past two decades, there has been growing support among educational researchers for design-based approaches to learning, based on findings that design projects provide rich opportunities for reflection, collaboration, and development of problem-solving abilities. Among the various instantiations of learning-through-designing, robotic design activities have been attracting growing interest among educators (e.g. Martin, 1992; McCartney, 1996; Druin and Hendler, 2000). One reason for the educational appeal of robotics activities is that they involve multiple types of design: physical design of structures and mechanisms and computational design of behavior. Studies have shown that robotics projects, by bringing together different types of design, reinforce core concepts about the design process (since learners experience these concepts in multiple contexts) while also offering learners multiple pathways into design experiences (Druin and Hendler, 2000).

Even as researchers have highlighted the educational value of robotics design projects, they have noted a sharp gender imbalance in the overall participation rates, at both the K-12 and university levels (Melchior, 2004). This imbalance is part of a broader trend in computer science and engineering. Although a previously existing gender gap in the overall *use* of computers has narrowed or disappeared, there are still significant differences in *how* people use computers. While girls and women use computers actively for communications and Web searching, they are far less likely to take computer-science courses and get involved with programming computers (Margolis & Fisher, 2003). This lack of participation is a cause for concern: an influential report from the National Research Council (1999) emphasizes the critical importance of "fluency" with digital technologies (where "fluency" is defined as "the ability to reformulate knowledge, to express oneself creatively and appropriately, and to produce and generate information (rather than simply to comprehend it) – and it argues that the skills associated with programming play a "central role" in becoming fluent. There are similar imbalances in other engineering disciplines, with girls and women less likely to become fluent as "builders," whether with structural, mechanical, or computational materials.

One reason for this gender imbalance, according to research studies, is that traditional approaches for teaching computer-science and engineering are not well-aligned with the interests of girls and women. As explained in a report from the American Association of University Women (2000): "Girls and other

nontraditional users of computer science – who are not enamored of technology for technology's sake – may be far more interested in using the technology if they encounter it in the context of a discipline that interests them." The AAUW report proposes that "computation should be integrated across the curriculum, into such subject areas and disciplines as art, music, and literature, as well as engineering and science." The report concludes that fluency "is best acquired when students do coherent, ongoing projects to achieve specific goals in subjects that are relevant and interesting to them."

1.5.2 Building on Prior Work

The Cricket Craft Clubs will build on best practices and lessons learned from other innovative and effective informal education projects.

A. Educational materials: The Cricket Craft Clubs build on FIRST LEGO League's successful model of announcing a new challenge each year that serves as a shared and inspiring focus for teams across the country and around the world (Melchior, 2004). However, instead of a rule-based competitive challenge, the Cricket Craft Clubs will focus on an open-ended exhibition theme that invites a range of possible projects. This variation aligns with math and science reform recommendations for educators to further equity efforts by supporting more collaboration and less competition (Beane, 1992; National Resource Council, 1996; Sadler, 2000).

The selection of video as a primary medium for introducing the Cricket Craft Club program and themes is based on findings from the FIRST LEGO League evaluation that coaches consistently requested a video to provide an introduction to the program (Melchior, 2004). The use of video for introducing the Cricket Crafts program also builds on experience from use of the Computer Clubhouse video (Peter Drucker Foundation, 1997), which has been effective in communicating the learning approach of the Computer Clubhouse to community members, mentors, and sponsors. Formative evaluation of the Cricket Crafts project will assess whether and how after-school program staff make use of the combination of video, online and printed materials.

The design of online structures for sharing for Cricket Crafts will apply successful strategies from other informal learning projects, including online art and science galleries developed as part of the NSF-funded Science Learning Network project, and the design of project galleries, mediated discussion areas, and other widely-used sharing mechanisms on the Boys and Girls Clubs' YouthNet and the Computer Clubhouse Village intranet (Diaz, 2003). The design of the Cricket Crafts blogging area will be informed by emerging literature on use of weblogs to further literacy and support collaborative learning (Huffaker, 2005).

The Cricket Craft Club activities will incorporate successful practices from Girls Inc.'s *Operation SMART* and other STEM gender-equity initiatives, including fostering collaboration, involving female mentors, exploring related career opportunities, and empowering girls to see themselves as capable of science, math, technology and engineering (Girls Clubs of America, 1998; AAUW, 2000). The project will also incorporate teen mentoring and other approaches developed as part of *Hear Our Voices*, an NSF grant that supports girls-only programs in Computer Clubhouses.

Cricket Craft Clubs will complement other educational programs designed to introduce hands-on design and engineering projects in after-school centers, including EDC's NSF-ISE-funded *Design It!* programs which emphasize use of everyday, low-tech materials to engage young people in design and engineering challenges. The *Rethinking Robotics* initiative will provide a different path into design and engineering projects, building on girls' interests in arts-and-crafts and computer activities. This approach will also complement the approach of the Museum of Science (Boston)'s new *Engineering Is Elementary* initiative which uses stories as an entry point for elementary school children and teachers to become involved in engineering learning and open-ended design projects.

There are several other organizations working specifically to engage girls in robotics, including Tufts University's Center for Engineering Education Outreach. Our initiative differs in that it offers a more

radical change from traditional robotics activities, focusing more on artistic expression through the use of light, sound, and music.

B. Staff development: The approach of the Cricket Craft staff workshops (including involving participants in firsthand experience with the project technologies and activities, and providing opportunities for group reflection, planning, and networking) builds on work of other NSF-funded professional development initiatives for informal science educators including the Playful Invention and Exploration Network project (Center for Children and Technology, 2005) and the Math Momentum in Science Centers initiative led by TERC and ASTC. The focus on providing workshops for staff from Boys and Girls Clubs and other community centers in low-income neighborhoods is supported by a recent FIRST LEGO League evaluation report that found working with Boys and Girls Clubs an effective way to reach and support teams in low-income neighborhoods (Melchior, 2005).

C. Evaluation methods: The evaluation for the *Rethinking Robotics* project incorporates approaches to assessing learning outcomes that go beyond the typical question-and-answer surveys, including innovative methods from Operation SMART's research tool kit (Girls Clubs of America, 1988).

1.5.3 Results from Prior NSF Research by PIs

The *Rethinking Robotics* project builds on the results of several successful NSF-funded projects conducted by the three Principal Investigators (Resnick, Rusk, Berg) over the past decade.

A three-year NSF grant (1997-1999) entitled *Beyond Black Boxes: Bringing Transparency and Aesthetics Back to Scientific Instruments* (CDA-9616444), with Resnick and Berg as PIs, provided support for early-stage development of the Cricket technology and educational activities. The project focused on the use of Crickets for building scientific instruments and conducting scientific investigations. We found that youth, by building their own scientific instruments, not only become more motivated in science activities, but also develop critical capacities in evaluating scientific measurements and knowledge, make stronger connections to the scientific concepts underlying their investigations, and develop deeper understandings of the relationship between science and technology (Resnick, Berg, & Eisenberg, 2000).

We began to explore the use of Crickets in informal learning environments as part of a three-year NSF grant (2001-2004) entitled *The PIE Network: Promoting Science Inquiry and Engineering through Playful Invention and Exploration with New Digital Technologies* (ESI-0087813), with Resnick and Rusk as PIs (and Berg as an active participant). In this project, we worked with a network of museums to develop a new generation of public programs that bridged the divide between physical and computational activities. The initiative built on science museums' rich tradition of using physical materials for hands-on science inquiry, introducing new technologies and activities that fluidly linked the use of physical materials with digital technology in creative inquiry. The Exploratorium is now leading an NSF-ISE initiative (with input from Resnick and Rusk) called *The Playful Invention and Exploration Institute* (ESI-0452567) that builds on the work of the PIE Network and is creating a structured professional development program of workshops and support materials for museum educators nationally.

In a current four-year grant (2003-2007) from NSF's ITR program, entitled *A Networked, Media-Rich Programming Environment to Enhance Informal Learning and Technological Fluency at Community Technology Centers* (ITR-0325828), with Resnick and Rusk as PIs, we are developing a new programming environment, called Scratch, designed specifically for youth at after-school centers in low-income communities. Resnick is also co-PI for the *Center for Bits and Atoms*, a large-scale NSF/ITR center (CCR-0122419). In particular, Resnick and his students are exploring how youth at community technology centers can use new personal-fabrication technologies (such as laser cutters and 3D printers) as tools for artistic invention and science learning.

Berg, in his work at Wellesley, has focused especially on broadening participation of women in science and engineering. His grant from NSF's Instrumentation and Laboratory Improvement program, entitled *Robot-Based Explorations in a Liberal Arts Environment* (DUE–9650969), supported the initial

development of the *Robotic Design Studio* course, which has helped introduce women at Wellesley to many of the big ideas of engineering (Turbak & Berg, 2002) – and served as an inspiration for the Cricket Craft Clubs in this proposal.

2. COLLABORATION

2.1 Project Team

The three Principal Investigators bring together expertise in informal science learning, robotics technologies, engineering education, and gender-equity issues.

Mitchel Resnick is Associate Professor of Learning Research at MIT Media Laboratory. Resnick's research group developed the ideas and technologies underlying the LEGO Mindstorms robotics construction kit, used by millions of kids around the world. He co-founded the Computer Clubhouse project, a network of after-school centers where youth from low-income communities learn to express themselves creatively with new technologies. Resnick was Principal Investigator for the NSF-funded PIE Network of museums, and is currently PI of an NSF-ITR grant to develop a new programming language (called Scratch) for use in after-school centers in low-income communities. He co-founded the Playful Invention Company to make Crickets and other research technologies more widely available.

Natalie Rusk, Researcher and Developer at the MIT Media Lab, specializes in new applications of digital technology in museums and after-school centers. For the past four years, she has served as co-PI and Project Director of the PIE Network. She worked for more than 10 years for the Science Museum of Minnesota, establishing the Learning Technologies Center and guiding the development of educational web resources, as part of the Science Learning Network (NSF NIE). She is also co-founder of the Computer Clubhouse project.

Robbie Berg is Professor of Physics in the Physics Department at Wellesley College. His current research centers on developing new computational tools for use in science and engineering education. Berg co-developed the Cricket technology and served as co-PI on the NSF-funded Beyond Black Boxes project, in which children used Crickets to design their own instruments for scientific investigations. Berg co-founded the *Robotic Design Studio*, in which Wellesley students use programmable devices to design, build, and exhibit their robotic creations.

2.2 Partners and Collaboration Process

MIT Media Lab. The MIT Media Lab is widely recognized as a world leader in the development of innovative digital media and information technologies. The Media Lab's Lifelong Kindergarten research group, which will play the lead role in the proposed project, has a well-established track record in the design and study of new educational technologies and creative learning environments. The primary contact will be Project Director Natalie Rusk (although PI Resnick will also be centrally involved).

Wellesley College. Wellesley College is a private liberal arts college devoted to the undergraduate education of women. Wellesley's 2300 students come from 50 states and over 60 foreign countries and include over 750 members of ethnic minorities. We expect that Wellesley's location near Boston, along with a student culture that enthusiastically embraces community service projects, will lead to the strong involvement of Wellesley students as mentors in the Boston-area after-school center sites. The primary contact at Wellesley will be co-PI Berg. Berg will be on sabbatical from teaching during the 2006-2007 academic year, and plans to focus his efforts on the *Rethinking Robotics* project.

Computer Clubhouse Network. The Computer Clubhouse project is a network of more than 100 after-school centers for youth (ages 10-18) in low-income communities, based at the Museum of Science in Boston. The Computer Clubhouse network was selected as a partner for the Cricket Craft initiative for several reasons: the Clubhouse's learning-through-design educational approach is well-aligned with the Cricket Craft model; participation of Computer Clubhouses ensures that the Cricket Craft initiative will

reach low-income youth; and the project PIs have a long and successful association with the Clubhouse network. The primary contact for the Computer Clubhouse Network will Brenda Abavanas, who manages the Clubhouse Network's gender-equity programs.

Boys & Girls Clubs. Boys & Girls Clubs of America comprises a national network of some 3,400 neighborhood-based facilities annually serving more than four million young people, primarily from disadvantaged circumstances. The mission of the Boys and Girls Clubs is to inspire and enable all young people, especially those from disadvantaged circumstances, to realize their full potential as productive, responsible and caring citizens. The primary contact at the national offices of the Boys and Girls Clubs of America will be Katie Kimple, who directs online technology programs.

To ensure involvement of the project partners in planning and revision of the Cricket Craft program, we will convene regular planning committee meetings (with local staff in-person and others joining via conference call). The meetings will convene at least once a month during the initial planning and launch of the project, with quarterly follow-up meetings. In addition to the project PIs, the planning committee will include:

- Brenda Abavanas, Program Manager, Computer Clubhouse Network
- Rachel Garber, Professional Development Coordinator, MIT Media Lab
- Joyce Shea, Computer Learning Coordinator, Boys and Girls Clubs of East Valley
- Franklyn Turbak, Associate Professor of Computer Science, Wellesley College

The planning committee members will represent and seek input from other staff at their organizations.

In Year 1, we will collaborate closely with staff from six Boston-area after-school centers, which will serve as pilot sites for the initial Cricket Craft Clubs. At least four of the six Cricket Craft Clubs will be located in Computer Clubhouse and Boys & Girls Club sites in low-income neighborhoods in Boston.

Building on the lessons learned from the pilot sites, we will run workshops (in Years 2 and 3) at regional and national conferences of the Boys & Girls Clubs of America and the Computer Clubhouse Network. We will also work with the leadership groups in these organizations, to help them incorporate Cricket Craft Clubs into their ongoing programmatic offerings for member sites.

We will also seek advice on planning, implementation, evaluation and dissemination from our Advisory Board, consisting of leaders from the fields of gender-equity, informal learning, and engineering education:

- Christine Cunningham, Vice President of Research, Museum of Science, Boston
- Kathy Helgoe Fett, Senior Project Manager, LEGO Educational Division
- Margaret Honey, Vice President of the Education Development Center (EDC) and Director of EDC's Center for Children and Technology
- Yasmin Kafai, Associate Professor of Learning and Instruction, Graduate School of Education & Information Studies, UCLA
- Maria Klawe, Dean of Engineering and Professor of Computer Science, Princeton University
- Margaret Pezalla-Granlund, Curator of Library Art and Exhibitions at Carleton College and Art & Science Coordinator, Science Museum of Minnesota
- Lynn Andrea Stein, Professor of Computer Science and Engineering, Olin College
- Karen Sullivan, Education Coordinator, FIRST

(For additional biographical information on the advisors, please see the supplementary documents.)

3. IMPACT

3.1 Audience

The primary audience for our initiative is **9-12 year-old girls.** We choose the 9-12 age range because research studies have shown that many girls begin to lose interest in math and science in that age range. The Cricket Craft Clubs would be designed primarily for girls, with at least half of the pilot and lead outreach sites offering girls-only Cricket Craft Clubs. However, we will also provide support for sites who want to run co-ed Cricket Craft activities, incorporating recommendations from research on gender equity within co-ed classes (Ching, 2000).

The project has the potential to reach girls in a broad range of after-school settings. Over the past 10 years, there has been a growing recognition of the importance of programs to support positive youth development in outside-of-school hours. In response, an expanding number of after-school and summer learning opportunities have become available in diverse settings, including community technology centers, housing developments, museums, and after-school programs within schools. These programs are interested in new activities that make use of computer technology to engage young people in learning. Many of these sites have joined in traditional robotics activities and we anticipate a similar interest in Cricket Craft activities. FIRST LEGO League has grown rapidly from 200 student teams in the US in 1998 to 4100 student teams in the US in 2004 (with an average of 8-10 students per team), and we will strive to achieve a similar rate of growth

Within the primary target audience of girls 9-12, we will pay particular attention to **girls in low-income neighborhoods**. Members of our research team have significant experience in these contexts through their work on the Computer Clubhouse project. Through the staff workshops and outreach efforts in this project, we expect CCC will reach more than 3,000 girls in low-income neighborhoods.

A secondary audience for the project is **program staff at after-school centers**. We have found from our previous work that program staff at after-school centers have a strong interest in learning about (and gaining hands-on experience with) creative uses of new technologies. We plan to reach more than 250 program staff directly through our workshops. We also hope to inspire thousands more to start their on own after-school Cricket Craft Clubs.

Although our primary audience is girls ages 9-12, we expect that our new robotics activities (based on artistic and musical expression) will also appeal to a **broader range of young people, including boys and girls of a variety of ages** (and even adults who missed out on this kind of activity when they were kids)**.**

To reach these audiences, we will build upon the extensive network of educators and parents that we have developed over the years. At the end of Year 1, we will send information about the Cricket Craft Clubs to our large mailing list of people and organizations who have expressed interest in working with our group in the past. We will also post information to mailing lists of community technology centers and after-school educators. We expect that these mailings will attract a core group of "early adopters" who will launch Cricket Craft Clubs in Year 2 (in addition to the BGCA and Computer Clubhouse sites). We expect that Cricket Craft Clubs will gain increasing national visibility during Year 2, leading to a significant increase in the number of Cricket Craft Clubs in Year 3. The MIT group has demonstrated the ability to attract broad attention and press coverage for its technologies and educational initiatives in the past, and we expect similar success with Cricket Craft Clubs.

3.2 Audience Impact

We expect that girls who participate in Cricket Craft Clubs will begin to:

- see themselves as designers with technology, not just users of technology

- think about technological objects in the everyday world in a new way, recognizing that objects in the world are designed (and could be re-designed)
- develop a better understanding of the process of design and of core engineering and computer science concepts

We expect that staff who facilitate Cricket Craft Clubs will:

- develop a broader framework for thinking about uses of new technologies, recognizing that not all computer activities need to be on-screen or online
- learn new ways to get girls engaged with new technologies
- develop new skills needed to support girls in creative engineering activities

3.3. Program Evaluation

Dr. Cynthia Char, of Char Associates, will serve as the evaluator for the project. Char Associates has over twenty-five years of experience in the evaluation of educational programs in science, mathematics and technology designed for children, schools, and community-based centers. They will design, coordinate, and implement a comprehensive three-year program of formative, summative, and process evaluation of the Cricket Craft Clubs.

An overview of evaluation activities, by year, is offered below, with a fuller description provided in the supplementary documents.

Year 1 (Formative Evaluation)

Formative testing of prototype materials will provide early feedback on which support materials and activities after-school educators and youth find most engaging and useful, and how Cricket activities, support materials, and leader workshops can be improved and refined. Testing will occur at the six local sites.

Year 2 (Formative and Summative Evaluation)

Year 2 evaluation efforts will continue to provide *formative feedback* on a larger set of piloted materials and with a broader, national audience. It will also gather feedback on how to optimize on-line support materials so that they may offer a sufficient means of stand-alone support for after-school leaders who do not attend a staff workshop.

Moreover, Year 2 will commence an initial round of *summative evaluation* to study the impact of the Cricket Craft experiences on participating youth and staff across the country.

Initial Study of Program Impact on Girls: Evaluators will study the project's effectiveness in enabling girls to acquire: a view of themselves as designers of technology; an understanding that technological objects are designed and redesigned; and fundamental concepts in design, computer science, and engineering. It will examine whether Cricket Craft Clubs were successful in attracting girls previously not involved with computer technology, and whether working with Crickets significantly deepened and extended girls' experiences and skills with technology design and computer programming.

Initial Study of Program Impact on Staff: Evaluators will study the project's effectiveness in enabling staff to learn and develop: 1) a broader framework for thinking about uses of new technologies; 2) effective strategies for getting girls engaged with technology; and 3) successful techniques for supporting girls in creative engineering activities. A particular focus is how Cricket Craft Clubs contrast with staff members' previous experiences with science, mathematics and technology programs for girls.

Year 3 (Summative Evaluation)

Year 3 will continue summative evaluation efforts with an investigation of participant outcomes on youth and staff, including a follow-up study of youth participants. It will also expand its focus to the impact of

Cricket Craft Clubs on host institutions, and on the emergence of a national, online Cricket Craft community.

Further Study of Program Impact on Girls: Two different summative studies will investigate the program impact on girls. A *follow-up impact study* of girls who participated in Cricket Craft Clubs in Year 2 will examine whether possible gains in interest and understanding of design, computers, and technology are sustained over time. Girls who chose not to continue with Cricket Craft programs will be asked for reasons for not doing so, and what might have enhanced past Cricket Craft experiences or increased their interest in continuing to participate in these activities.

The second study will investigate the *emerging Cricket Craft online community*, and girls' participation in that community. Evaluators will track the Cricket Craft online discussion and blogging areas to examine the ways in which girls are posing questions, exchanging ideas, offering advice, posting projects in on-line exhibitions, and reflecting on experiences.

Further Study of Program Impact on Staff and Host Organizations: Evaluators will study whether Cricket Craft Clubs increased staff members' repertoire of technological skills, understanding, and pedagogical approaches to better serve girls as well as boys. Also examined will be the program's impact on the host institutions, and whether Cricket Craft activities enhanced organizations' educational and technological capacities and offerings. Part of this investigation will examine the emergence of the broader online community and the use of common Cricket Craft themes, and whether youth, staff and institutions now are more strongly connected to other youth organizations across the county in this shared endeavor of offering technological experiences.

Years 1, 2 and 3 (Process Evaluation)

A *process evaluation* will investigate how after-school sites chose to implement Cricket Crafts Clubs, and the ways in which the settings' physical, social and cultural context (e.g., technological facilities and expertise of staff; different host organizations' approach to educational and enrichment offerings in the setting; cultural backgrounds and gender of youth participants and staff) influenced program implementation and effectiveness. Two particular foci will be an examination of whether the gender composition of teams and program settings (i.e., all-girl versus co-ed) significantly affects the type of teamwork, design process, productivity and creativity generated, and the extent to which the culture of the national or local youth organization significantly shapes the nature of the educational program experience.

Data will be collected with a variety of methods, including observations of program sessions and culminating exhibitions, written and online surveys, and interviews with participating youth, staff leaders and administrators, examination of Cricket Craft Club products (technology artifacts) that youth create, and monitoring of online activities of the Cricket Craft community. Data collection techniques and analysis efforts for all phases of work will incorporate an optimal combination of quantitative and qualitative data.

Evaluation findings will both contribute to the body of research on the use of technology in informal learning settings and the value of a new genre of robotic activities for girls, and inform further creation and revision of Cricket Craft activities, support materials, online community offerings, regional and national staff workshops, and broader dissemination efforts.

3.4 Strategic Impact

Our goal is to broaden the ways people think about robotics and engineering, and provide new models for introducing robotics and engineering to broader and more diverse audiences. Our project team has a strong track record for getting our research-based technologies out to the world in large numbers. The LEGO Mindstorms robotic construction kit, based on Media Lab research, has been used by millions of youth around the world. And the Computer Clubhouse project now has 100 sites serving more than 20,000 young people in low-income neighborhoods. We believe that the Cricket Craft Clubs – and related technologies and ideas – have the potential to achieve similar success.