

INTERACTION MATH: a Collaborative Informal Learning Community

I. IMPACT

A. Strategic Impact: Interaction Math will unite a diversity of professionals and formal and informal institutions to develop and study a new type of collaborative, online community-based learning service for enriched informal learning. Capitalizing on the high visibility of the Math Forum @ Drexel (mathforum.org) with its two million per month visits, and over one million pages of mathematics content, Interaction Math will both demonstrate and disseminate broadly, the possibilities of enriched learning afforded by online collaborative learning.

Moving the Math Forum from a text-based, asynchronous community, Interaction Math will comprise an online community learning center where members gather in real time to create and share learning experiences facilitated through the use of chat (a very compelling medium for young learners), dynamic mathematics and gaming software, and volunteer math enthusiasts/professionals acting as online mentors. As other providers of rich informal learning content learn of the feasibility of collaborative online learning spaces, we expect that interest in this field will explode.

With the raw materials of a digital library of math tools, successful web learning services, research efforts around online collaborative learning, and access to communities of diverse learners, the Math Forum and its partners are uniquely positioned to create, study, and disseminate this new collaborative learning environment. This will provide a model for educating the public about science through virtual, collaborative informal learning communities across other science, technology, and engineering disciplines utilizing other digital libraries.

B. Immediate Impact: For the nation's grades 3-12 learners, including those from underrepresented groups, Interaction Math will provide rich learning opportunities where students collaboratively build

- Interest and positive experiences with mathematics, cultivating their own approach and connection to mathematics,
- Confidence and mathematical understanding that increases their ability to become autonomous learners and users of mathematics in their daily lives, and
- Knowledge of and appreciation for the possibilities and benefits afforded by STEM careers.

A typical visit to Interaction Math might look something like this: Upon entering the Interaction Math website, a student logs in and checks on feedback from the problem she worked on last week. Noticing a link to a blog written by one of her Interaction Math friends relating to the theme of "math anxiety", she goes to check it out. She posts a comment, then returns to access her group to work collaboratively on their new problem. The group is mentored by Sarah, an engineering student from a minority serving institution. Sarah had seen the program advertised on her department's bulletin board. She liked the idea that she could work online from her dorm room for an hour per week to "give back".

Five students from all across the country have been working together in the group weekly for about three months. They come to Interaction Math for a variety of reasons. Some enjoy math and come to work on math challenges. Some lack confidence in their math skills and come to build up their abilities; others enjoy the technology and like using math applets, others enjoy the artistic elements of the *Math Images*; some come to learn more about college and careers, and others like the chat and are motivated by the opportunity to work with other people their age. After a few minutes of preliminary talk, they start to work on their new problem.

At one point, two people go off to search the Math Forum’s Internet Library for help with a concept. Two others use a shared graphing calculator to graph the function. Another draws a figure with a shared drawing package. They come back together to try to negotiate a consensus on how to approach the problem, and decide to come back the next day to continue to work on it. The students like to talk to Sarah about college life, and she gives them information about what engineering is like and points them to a page at the Interaction Math website for more information. The chat took about 30 minutes, and the group members enjoyed the experience. The next day at the appointed time, they once again discuss the problem, and submit a collective solution with explanation, with one dissenting opinion. Later, the group members see positive attention their solution receives from others in the community and get ideas about aspects they hadn’t considered.

1. Target Audience: Interaction Math is for learners in grades 3-12 including those from groups underrepresented in STEM. We will proactively recruit and serve underrepresented groups, including girls, underrepresented minorities, and urban and rural populations, reaching this audience by advertising through schools with high-minority, rural, and urban populations and engaging community-based organizations that already have extensive penetration into these communities. We conservatively project levels of engagement over ten years that are reflected in the table below based upon 2 million visits per month, Math Tools having registered 6000 adult users in two years, 113,000 different users having submitted 270,000 solutions to the Problems of the Week service in 10 years, and our connection with approximately 500 community-based organizations.

Activity Level	Cumulative Target Engagement
Visits to the site	3 million
Registered users	100,000
Extended users	50,000 (at least 3 sessions)

Demographic information will be collected on registrants and disaggregated by ethnicity, gender, age, and geography. See more information on this in the Evaluation section.

a. Meeting Target Audience Needs: Interaction Math is based on the premise that all students must be afforded supportive opportunities for mathematics learning experiences that 1) connect to learners’ interests 2) provide engaging tasks and activities that are challenging but accessible, 3) reflect relevance and significance to their lives, 4) meet their need for community and belonging, and 5) provide an opportunity for self expression and creativity [1,2,3,4,5,6]. Online collaborative learning shows tremendous potential for meeting all of these mathematical learning needs in ways that school experiences have not.

Reports continue to show U.S. students falling behind other countries in math achievement, most likely for systemic reasons [7,8]. Too few U.S. students leave school mathematically prepared or motivated for science, technology, engineering, or mathematics (STEM) majors, creating serious consequences for the nation's technical work-force [9, 10,11].

Operating as a filter for STEM careers, math achievement is even lower among racial/ethnic minorities, low socioeconomic groups, and females. Factors in schools contributing to the achievement gap of poor and minority students have been well-researched and include: low expectations, inadequate human and fiscal resources, and inadequate teacher [12, 13, 14, 15, 16, 17].

The Math Forum is engaged in an intervention with Temple University Partnership Schools of the School District of Philadelphia and daily sees firsthand the challenges of systemic reform within schools suffering from dysfunctional mathematics instructional programs. How many children within these systems might realize the value of learning and using mathematics if given the opportunity for high-quality learning experiences? How many might choose STEM careers if given the knowledge, inspiration, guidance, and confidence from role models about the benefits afforded there?

b. Appealing to Target Audience Interests: America's youth today have been characterized as the "instant messaging generation" [18], and Interaction Math will use the cultural contexts of chat and the Internet to engage teens in informal science learning. A 2001 study revealed that 73% of youth ages 12 through 17 uses the Internet (surely even higher in 2005) [18]. Almost all online teens (94%) use the Internet to do research for school. The proportion of online girls that has used instant messaging (IM) exceeds that of boys -- 78% for girls and 71% for boys. Also, girls begin IM at an earlier age, with 72% of girls 12 to 14 using the service, compared to 60% of boys the same age who use IM.

We are particularly aware that in order for Interaction Math to be sustained, activities must appeal to members' interest. In the language of Resnick, learners must perceive the activities as "cool" [19]. Research shows that much of teens' time spent on the Internet is devoted to support for school assignments, but in order to engage them in *voluntary* learning as we intend to do, the activity must support their "social and entertainment gratifications" [20]. In other words, for Interaction Math to be successful, it must feel like a place where participants can connect with peers and concerned adults [21], and it must be fun.

c. Reaching Underrepresented Groups: Even though access to Internet technologies among the nation's poor and minority population is a challenge to this project, **its staff will only consider Interaction Math a success if it reaches and supports the learning of students from underrepresented ethnic/minority groups and both male and female students.** Project planners have set a minimum expectation that 50% of the participants will be female and 25% will be underrepresented minorities and have implemented strategies to ensure this reach.

Give Attention: Appointment of a Co-PI committed to diversity, someone responsible for ensuring that it happens. Before coming to the Math Forum, Cynthia Lanius served as Executive Director of Rice University's Center for Excellence and Equity in Education. In that position, she developed programs to increase participation of underrepresented groups. (See Biography for details)

Gain Access: Partner with community technology centers (CTC) and other minority serving institutions Interaction Math fulfills a critical need for CTCs for quality mathematics content and provides us access to an essential segment of our target population. A report published by the Children's Partnership cites lack of appropriate content as a major obstacle to effective use of technology by low-income and underrepresented minority students [22].

Acquire Knowledge: Partner with researchers with expertise in this area Interaction Math seeks advice and counsel of advisors familiar with the needs and interests of the target population. We have immediate access to 50 researchers through the Institute of African American eCulture and with leaders in this area and with our board of advisors. Carlos Castillo-Chavez brings the support of the Society for Advancement of Chicanos and Native Americans in Science and two organizations that he leads for minority students (See letters of support.)

Provide Role Models: Partner with universities and community colleges that provide role models for online mentoring. Minority and female students will experience online mentors with whom they can connect, coming from similar backgrounds. Interaction Math will develop its mentoring system with mentors from the Community College of Philadelphia. (CCP) (See letter of support.)

Provide Multi-cultural content: Partner with groups who can provide content with special appeal to ethnic/minority groups or females. Minority undergraduates from the Mathematical and Theoretical Biology Institute will work with our educational resource developers to create interdisciplinary materials designed to appeal to diverse audiences. We will also give extra attention to locate existing multi-cultural materials. For example, when studying fractal geometry, *African Fractals*, by Ron Eglash, can supply a wealth of interesting concepts [23].

To reiterate, we realize that without serious, continual attention we will not reach nor sustain the diverse audience that we intend. At the same time, we are excited by the prospect of engaging a much broader audience than ordinarily would participate in such endeavors. We also believe that the measures designed for diversity wind up benefiting everyone. This will be of highest priority in this initiative.

2. Interaction Math Learning Goals: For the nation's grades 3-12 learners, including those from underrepresented groups, Interaction Math will provide rich learning opportunities where students collaboratively build

- Interest and positive experiences with mathematics, cultivating their own approach and connection to mathematics,

- Confidence and mathematical understanding that increases their ability to become autonomous learners and users of mathematics in their daily lives, and
- Knowledge of and appreciation for the possibilities and benefits afforded by STEM careers.

3. Meeting our goals through collaborative learning (CL): Students interacting with one or more peers to solve a problem enlivens and enriches the learning process and provides an effective social context for learning [24, 25, 26, 27, 28]. CL consists of interactive processes, like seeking and giving feedback, asking for help, talking about errors, experimenting, discussing failure, looking for information from outside, critiquing, evaluating, and developing a collective vision [29] all in real time, processes that informal online learning has not yet provided. CL has positive social consequences, where members must learn to resolve differences and interact appropriately in order to reach its distinctive aim -- to build consensus among group members.

Incorporation of CL processes into online learning is not trivial, neither in its importance nor in its challenges. Researchers Stahl, Weimar, and Shumar recently targeted the Math Forum's online community to test two such challenges -- how best to automate forming online groups and how best to support the collaborative learning of the groups through scaffolding provided by software and highly leveraged human facilitation. Interaction Math will capitalize on the experience gleaned from the Virtual Math Teams (VMT) research project and apply it to the development of a productive public service. In the context of the VMT research, the Math Forum has already held over 20 small chats with students representing the target group. While this research has been more focused on tasks that support formal learning, preliminary results clearly indicate both the high level of engagement that chat engenders as well as the need for effective software functions that facilitate both communication around mathematical objects and group participations, so that students learn to make good use of each others' contributions.

While we know that collaboration plays a major role in constructive cognitive development [30, 31, 32] informal online learning continues to be structured in ways that assume learning is a matter of delivery, merely transferring information from individual to individual. Informal learning websites contain some of the richest science content on the web, and creating opportunities for collaboration, communication, problem-solving, and articulation of concepts, solutions, and processes around that material will foster true inquiry-based experiences.

Considerable research has been conducted on conditions that foster collaboration: group composition, the group's task, and the communication medium [32,33,34 24,]. It is generally held that small groups work best, and Interaction Math expects to form small groups of 4-5, although we'll experiment with this factor as we proceed [35]. The most intensely studied variable in group composition is group heterogeneity (age, intelligence, development, school performance, gender, ethnicity/race). Results indicate there exists some theoretical optimal heterogeneity, i.e. some difference of viewpoints is required to trigger interactions, but within the boundaries of mutual interest and intelligibility. Heterogeneity can favor the low and average achieving students more than homo, even

though homo might promote interaction better from all members. [34 ,24] We will also look at the effects of heterogeneity on group function.

Effective collaborative tasks are those that promote group members' reaching a common goal and obtaining mutual understanding. The essence of a consensus-building task is that differing viewpoints can be articulated, considered, and accommodated. In this regard, mathematics problem solving is an optimal collaborative task [36]. Solutions will be submitted as a group, although a member will be allowed to register a dissenting opinion if consensus cannot be reached.

Resnick may have been the first to see the Internet as a collaborative learning center.

The clubhouse philosophy suggests a third, very different, vision of the Internet. We see the Internet as a new medium for collaborative construction—a new opportunity for students to discuss, shares, and collaborate on constructions [37].

With its strong “coolness” appeal for youth, the chat medium has the potential to draw a large number of youth into Interaction Math. Our past work shows that we have the technical and human capacity to produce the work that we are proposing, and a strong team of collaborators believes in, supports the project, and commits to its success.

II. COLLABORATION: Development of Interaction Math initiated new partnerships that already extend beyond the scope of this project. For example, through efforts to recruit online mentors at Community College of Philadelphia (CCP), long term planning for support of other projects has begun. Interaction Math is a highly collaborative effort of a strong, diverse team. Our experience shows that this diversity will lead to more interesting applications and more effective outreach and support for participating learners. In particular, the Math Forum looks forward with excitement to learning from its partners and others in Informal Science delivery.

Interaction Math will be a primary initiative of the Math Forum @ Drexel with some of its most senior and talented staff members charged with its development. The first 3 years of development will be highly labor intensive, but Math Forum experience has taught us to give careful attention to design and programming early in the project, so that in its permanent stages, it can be sustained with relatively minor attention. Consequently, the fourth year, staff support will be cut in half, and in the fifth year, in half again. This will give us sufficient time to build structures that enable long-term non-NSF support.

A. Staff

PI Gene Klotz, *Professor of Mathematics* and *Founding Director* of the Math Forum is a pioneer of numerous successful mathematics online learning projects and communities. Gene will have primary responsibility for all aspects of the project, especially math content and mathematics problem solving technologies.

Co-PI Steve Weimar, longtime *Director of the Math Forum*, directs a team of approximately 25 researchers, educators, and technologists in a multi-faceted center for research and development of mathematics education. As *Interaction Math Program Director*, Steve will provide overall program direction, including fiscal, and staff management, recognizing that most staff are Math Forum staff members.

Co-PI Cynthia Lanius, *Associate Director of the Math Forum*, has 12 years experience teaching high school math in urban settings and 10 years designing and managing diversity programs. Cynthia will be responsible for overseeing the program's efforts to engage a diverse audience.

Co-PI Gerry Stahl, *Associate Professor in the College of Information Science and Technology* specializes in computer supported collaborative research and has developed a series of collaboration computer systems. Gerry oversees research on collaborative learning at the Math Forum and will oversee moving the research to practice.

Annie Fetter, *Mentor Services manager* will manage mentor development and oversee student mentoring. Annie has over 10 years at the Math Forum and much of its success can be attributed to her knowledge of mathematics and of supporting learning of mathematics online. Annie authors Geometry PoWs, and mentors students and teachers in four K-8 Philadelphia schools.

Suzanne Alejandre, *Educational Resource Developer*, has 17 years experience teaching math and technology in a school-wide Title One school in southern California. Suzanne authors Pre-Algebra PoWs, the 6th and 7th grade Temple Partnership PoWs, and mentors students and teachers in four K-8 Philadelphia schools.

David Tristano, *Software Developer*, has programmed the complex MathTools website and will apply that experience to development of the Interaction Math site.

Graduate Student in the College of Information Science and Technology, will be primarily responsible for prototyping and software development in Perl and Python for extensions to the Math Forum software.

A Program Manager, to be named, will be charged with working day-to-day with all aspects of the project. She will have a strong background in community-based informal science learning environments.

B. Advisory Board Our advisory board brings together a multidisciplinary and multicultural group of innovators, with expertise in the fields of mathematics education, informal learning, diversity, and community development. Members have committed to two virtual meetings per year which will be held through Interaction Math's collaborative online environment. Annual reports will be submitted to the board for their feedback.

Chair, Roscoe Giles, Director, Institute for African American E Culture

John Mahoney, Teacher, Benjamin Bannecker High School, Washington, D.C.

Michele Masucci, Temple University, an NSF ITEST PI

Sarita Nair, Project Director, Gender, Diversities & Technology Institute, Education Development Center, Inc.

Hope Yursa, Math Coordinator, School District of Philadelphia

Anne Papakonstantinou, Director, Rice University Mathematics Leadership Institute, an NSF Mathematics Science Partnership Initiative

Nora Sabelli, Senior Science Advisor, SRI's Center for Technology in Learning

Rachel Bower, Applied Math and Science Education Repository (AMSER), University of Wisconsin, Madison. AMSER is an NSDL project designed to help meet the needs of community and technical colleges.

C. Consultants

Carlos Castillo-Chavez, Joaquin Bustoz Jr. Professor, Departments of Mathematics and Stats, Arizona State University. Carlos, 1997 winner of NSF's Presidential Award for Excellence in

Mentoring, will advise and supervise students from the Mathematical and Theoretical Biology Institute (MTBI) working on Interaction Math. He will also engage and supervise minority high school students from the Institute for Strengthening Understanding of Mathematics and Science (SUMS) as Interaction Math participants. See letter of support for more details on Carlos' involvement and also see Carlos' biographical sketch.

MTBI students will develop Interaction math activities and will mentor students online as they work through the projects. **MTBI** is a summer research program for underrepresented minority undergraduates that encourages participation in graduate education.

SUMS students will participate, test, and give feedback and advice on the development of the online collaborative environment.. **SUMS** is a program for underrepresented minority high school students to take university courses summers of their junior and senior years of high school.

Margaret Hitzenko and Elena Koublanova, *Mathematics Instructors, Community College of Philadelphia*, will supervise community college mathematics development and engage student consultants. See their letter of support.

Community College of Philadelphia students will participate as mentors, to test and give feedback and advice on the development of the online mentoring services.

K. Ann Renninger, *Professor of Educational Studies, Swarthmore College*. Ann is a leading scholar of online learning having conducted formative evaluation at the Math Forum since its inception. Central to this capacity is the gathering of formative data about users' needs and interests, how the Math Forum services meet those needs, and how the Math Forum can better serve the users. Ann will lead a focused research project on interest and learning in the online collaborative environment.

Wes Shumar, *Associate Professor of Anthropology, Drexel University*, works in tandem with Ann to provide ethnographic evaluation to the formative evaluation. Ann and Wes have published dozens of papers and articles in scholarly journals about their findings on Math Forum projects, and in 2002, Cambridge University Press published, *Building Virtual Communities*, an edited volume. Wes will lead a focused research project.

D. Contractors: External Evaluators, The Lead Center: Since 1994, the Learning through Evaluation, Adaptation, and Dissemination (LEAD) Center has worked with faculty and program administrators nationwide to evaluate the impact and improve the strategies of hundreds of educational programs. LEAD's mission is to provide high-quality formative and summative evaluation for programs in education, technology, health, and social services. See the evaluation section to see more about the LEAD.

E. Interaction Math Organizational Partners include: the Math Forum @ Drexel, the Institute for African American Eculture (IAAEC), the Children's Museum of Houston, and Technology for All.

The Math Forum @ Drexel (<http://mathforum.org/>) is a Drexel School of Education mathematics educational research and service center that has developed one of the most successful applications of the Internet to education through services that link higher education, pre-K-12 formal and informal learning institutions, research communities, professional organizations, and the general public. The Math Forum website delivers problem-solving programs, mentored learning services, digital libraries of mathematics tools and community-developed resources, discussion forums and other mathematics-

related services for students, teachers and the public. As an intellectual haven for about a million people, it demonstrates how the Internet can host large global learning communities. From its inception in 1992 to the present, much of the Math Forum's work has been "informal," with students voluntarily accessing the Math Forum outside of school hours as a resource to support their learning or simply to explore an interest.

IAAEC is an NSF-funded research community that brings together a number of African-American computer scientists, social scientists, educators, entrepreneurs, and others committed to accelerating the development of viable electronic culture within the African-American community. IAAEC activities include: multidisciplinary basic research in IT with theory closely linked to practice; development of culture-specific technologies, pedagogies, and assessments; and research on scalable deployment models. Researchers in IAAEC are leaders in their respective fields and will provide expertise and advice on Interaction Math development. (See letter of support from Roscoe Giles, Executive Director who will also chair our Advisory Board.)

Through Interaction Math, **The Children's Museum of Houston (CMH)** and the Math Forum have formed a strategic alliance that holds much promise for both institutions for this and future work. Through CMH's ACCELERATE, fourteen community learning centers in the Houston area will participate in Interaction Math through their after-school grades 3-6 mathematics programs. Project ACCELERATE was begun in 2001 in response to assessment that after-school computer learning labs often do not have adequate learning resources for their participants. (See letter of support).

Tech for All empowers under resourced communities through the tools of technology. By partnering with local community-based organizations, corporations, foundations, technology providers and public agencies, Tech for All creates educational, economic and personal opportunities for low-income persons and the communities in which they live. Tech for All works with over 185 Houston area organizations operating CTCs and 300+ organizations doing the same across the United States. CTCs has committed to incorporate Interaction Math activities into its programs (See letter of support).

3. INNOVATION Interaction Math is a web-delivered program, but is much more than merely a website. A multi-faceted **program** of mentored services built on rich mathematical content and problem solving tasks and tools, it will act as a virtual community center where members gather to access the highest quality mathematics tools, tasks, specialists, to experience shared learning.

C. Primary Project Deliverables include:

1. Hosting mentored problem solving service

Interaction Math's most influential innovation will be the development of a *collaborative* problem solving service, fashioned after its Problems of the Week (PoW) service.

Since 1994, the Math Forum has delivered and researched online problem solving through its PoW service. Hundreds of students per week submit solutions and explanations online and receive guidance and feedback to revise and re-submit through an online mentoring service. Prior evaluative research has demonstrated that both weak

and strong students who submit over time make more connections to, generate more effective strategies for, and work more independently on math challenges [38,39].

Interaction Math will use the PoW concept including its key components of challenging, non-routine problems, online mentoring that gives feedback and guidance, then follow-up solution and explanation revision. However, Interaction Math adds the excitement of collaboration, delivering the PoWs to small groups of 4-5 students synchronously working together online using chat technologies.

When Interaction Math is at full operation, collaborative sessions will be held eight hours per day, Monday through Friday, from 4:00 P.M. until midnight Eastern time to provide for east to west coast time zones. Saturday and Sunday hours will be from 12:00 noon - 8:00 PM Eastern.

Why not voice or video? Interaction Math will use text chat. Even though voice and video interaction are available over the Internet, limited home high bandwidth capabilities dictate text chat for now. We may make small experiments with voice/video later in the life of the project as bandwidth issues change.

2.Math Content Collection

Developing, testing, and implementing an extensive collection of non-routine Standards-aligned mathematics problems designed for exploration with web-based tools for discussion and solution by small groups of learners.

We focused on problem solving, rather than some other type of mathematical activity as the basis for collaborative learning because it can create for learners a new, exciting approach to mathematics. Schoenfeld calls problems delivered in this approach “starting points for serious explorations, rather than tasks to be completed” [40]. When problems are delivered to groups in Interaction Math, they will be mere starting points. Groups may invent a better problem. They may extend that problem to a richer, deeper, one, or a long-term exploration of a whole area of mathematics that it introduces.

Problem solving is one of three domains in which “equity in proficiency” presents substantial challenges according to the Rand Mathematics Study Panel [41]. Further, the National Council of Teachers of Mathematics *Principles and Standards* outlines a vision for doing mathematics that includes a strong focus on conceptually-oriented problem solving that stresses reasoning.

A problem-centered approach to teaching mathematics uses interesting and well-selected problems to launch mathematical lessons and engage students. In this way, new ideas, techniques, and mathematical relationships emerge and become the focus of discussion. Good problems can inspire the exploration of important mathematical ideas, nurture persistence, and reinforce the need to understand and use various strategies, mathematical properties, and relationships. [36]

The program will need a collection of approximately 500 problems to deliver one per week to all 10 targeted grades. (After problems are tested and approved, they can be re-used yearly as students move up through the grade levels) About half of the mathematical

content in the program will be adapted from some of the most effective existing problems in the Math Forum’s database of problems (See Supplementary Documents for examples of problems.) This cost effective approach takes advantage of the significant wealth of inquiry-based materials developed and tested over the years. The balance of the activities will be newly developed explicitly based on the program goals, designed to appeal to a diverse audience, and age appropriate. Undergraduate minority students from the BTMI program will help to develop and field-test interdisciplinary problems with special appeal for minority students.

3. Website Development

Designing, implementing and evaluating an online, monitored collaborative space for groups of learners to work together in small groups on math activity

Much of the programming required for Interaction Math’s advanced user-profiled type of website has already been developed at the Math Forum in its MathTools site, another highly cost-effective aspect of this project. Consequently, much of the programming will be adaptive, rather than creative of something entirely new.

Design Principles: The web site will be designed so that users can expeditiously locate resources and activity appropriate to them. Like other “informal” learning environments, it must be inviting and engaging. Text and images will be non-stereotypical. Interaction Math will be seamlessly integrated into mathforum.org so that learners will be connected from and to other Math Forum services – the MathTools Digital Library, Ask Dr. Math, and the Internet Math Library – for further help and support, both individually and as a group.

Based on our previous web work, we will design simple pages that load fast, without clutter, but with “kid appeal”,-elicit and act on user feedback and evaluation, and-use multi-media judiciously, such as a java applet for a math game.

User Profiling: We will implement a user profiling system that connects characteristics of visitors to math collaborations. We will also track users with cookies to follow user movement through the site and time spent in various areas. These tools will help us build profiles of individual users in order to customize their pages and to connect them with other group members and mentors. We hope to provide users with appropriate recommendations as a result of their past use and interests. We would like to use friendly, inviting questions, such as “Have you seen these items yet?” (and provide them with a list based upon past use) to help them find new learning opportunities.

We will implement an “Amazon.com” model for materials delivery that will provide feedback to users, perhaps in the form of “members who liked this activity, also liked this other one.”

Privacy Policy: Interaction Math’s privacy policy (See Supplementary Documents) and use of student information is stringent, based on our current policy and reads in part

If you are under 13, please have your parents/guardians read this policy and approve your use of our services. If you are under 13 and you participate in the

Interaction Math services, you must have your parent register you for participation. At any time, your parents have the right to request that we remove your personal information by e-mailing us or by contacting us via postal mail or telephone (800)756-7823.

A link to the privacy policy will appear at the bottom of every page. As we implement our user database and gather information from site visits, and as custom and legislation dictate, we will update the privacy policy accordingly. User safety and privacy has always been and will continue to be of utmost importance to the Math Forum leadership.

4. Mentor Development: Adapting and implementing a two-pronged mathematics mentoring service that gives learners feedback and guidance on mathematics within the collaborative environment The Math Forum has effectively used adult online mentoring around mathematical problem solving for almost 10 years in several of its programs, most notably Ask Dr. Math and the Problems of the Week, [42,43] training a diverse group of professionals and math enthusiasts, and most recently, pre-service education majors. Training is done online and is a combination of guidance, practice, and apprenticeship. To attract sufficient numbers and a diversity of volunteers for Interaction Math, we will

1. Request volunteers of teachers and other visitors to the Math Forum site,
2. Contact Math Forum partners, collaborators, and supporters and professional organizations to advertise for volunteers on their mailing lists and Web sites
3. Email flyers to university math departments, especially among minority serving institutions, and
4. Email flyers to businesses, industries, service organizations, and other professional organizations.

Two types of mentoring will be needed for Interaction Math: 1) Collaborative learning facilitation and 2) Solution feedback and support.

Mentor Responsibilities:

1. Participate in collaborative training, orientation, and apprentice sessions through Interaction Math's collaborative online environment,
2. Commit at least one hour per week,
3. Provide effective mentoring [44],
4. Submit an online assessment form that includes strengths, areas of improvement, and insights, and
5. Report immediately any student violation of rules and responsibilities.

Effective **mentoring of collaboration** includes: guiding team experiences as unobtrusively as possible; supporting positive collaborative behaviors and discouraging negative ones, sharing discipline- and career-experiences from which others may benefit and learn.

Effective **mentoring of problem solutions** includes; providing feedback, encouragement, and support on both the mathematics and communication of written team submissions.

Mentor Training: The Math Forum has 10 years experience training online volunteer mentors for individual work and will leverage that experience for mentoring collaborative work. Training will include 1) **Guidance** on good mentoring, 2) **Practice** with simulation problems and chat scripts, and 3) **Apprenticeship** with experienced mentors. The Math Forum will employ students from the Community College of Philadelphia as *Mentor Associates* as it adapts the mentor training program to a collaborative model. This will allow us to test the system with paid consultants as we develop the volunteer force.

4. Career Information Development

Developing a careers service that educates and motivates visitors regarding STEM careers

In the absence of role models in their everyday lives, students need examples of women and minority scientists and engineers that can provide inspiring, yet realistic views of what those careers entail. Static information abounds on the web, but engaging students personally. By providing detailed information about the experiences and lives of women and minority scientists and engineers, the biographies on these Web sites may be useful in countering existing cultural stereotypes of women scientists and engineers and initiating changes in perceptions needed to narrow the gender gap in science, engineering, and technology.

5. Math Images

One of our innovations will be the use of visual "math images" as the basis for some of our PoWs. There are now many sites which combine beautiful and intriguing images which come from mathematics, some of it school level [45, 46,47]. These sites often have explanatory material along with them and many are slightly different from what is taught in school mathematics, so their study will not impinge on students course work, although it will often extend their course work to make it more meaningful and interesting.

In addition, several mathematicians who work in advanced areas are keenly interested in bringing their ideas to the pre-college and have committed to working with us on this project. Two of the best known are Robert Devaney (complex dynamics)[48] and Jeffrey Weeks (the shape of space)[49], and Thomas Banchoff (objects beyond the third dimension)[50,51,52]. All of the cited sources have explanatory material, often with historical notes, often with animations, and will be a rich source for problems.

To make this project cost-effective we will not develop the math image material ourselves, but a great deal exists on the web, and many of its owners see this as a powerful dissemination tool for them. To help find what is out there and to encourage the production of further material useful to us, we will approach owners of sites we know which contain beautiful math imagery, and offer to construct a web ring of visual math sites. We will describe our project, give exemplars of what we're looking for, and ask them to suggest other sites which might belong.

B. Project Work Plan

Year 1 – Initial Working Team and Project Development

- Work groups: Assemble team; hold focus group to review six months goals; Deliver 25 collaborative sessions
- Adapt and Test software environments to support collaborative knowledge building
- Math Content Collection: Adapt 50 problems and create 50 new ones
- Website Development: Develop alpha version of website; deploy and test
- Mentor Development: Engage 20 CCP students, adapt and test training system; begin recruiting mentors
- Career Development Section: Engage BTMI students for test of career mentoring experiences
- Evaluation: Collect baseline outcome data
- **Year 2 – Adapting Work on Initial Feedback**
- Work groups: Deliver 50 collaborative sessions;
- Adapt and Test software environments to support collaborative knowledge building
- Math Content Collection: Adapt 50 problems and create 50 new ones
- Website Development: Add personal choices functionality; deploy and test
- Mentor Development: CCP students train and oversee mentors
- Career Development Section: BTMI students oversee career section
- Evaluation: Meet with Formative Evaluators for feedback
- **Year 3 – Full Development**
- Mentored problem solving sessions: Deliver full-time
- Math Content Collection: Develop 100 new problems and adapt 100 others
- Website Development: Enable and test full functionality
- Mentor Development: Automate sign-up and training; full cadre of mentors
- Career Development Section
- Evaluation:
- **Year 4 Initial Dissemination and Sustained Phase**
- Mentored problem solving sessions: Deliver fulltime, automate as possible
- Math Content Collection: Develop and test automated scheduling system for PoWs
- Website Development: Ensure website, database
- Mentor Development: Train 100 new volunteer mentors
- Career Development Section
- Evaluation: Collect baseline outcome data;
- **Year 5: Final Research, Final Sustained Phase, and Broad Dissemination**
- 1. Mentored problem solving sessions: Deliver 320 chat sessions
- 2. Workshops and presentations at conferences, CTCNet and ASTC, and local centers
- 4. Mentor Development: Implement
- 5. Research publication and presentations at national conferences

C. Program evaluation will be composed of both formative and summative evaluation. Formative evaluation will be conducted by long term evaluators of the Math Forum, Wes Shumar and Ann Renninger and will guide the development of the many facets of the project.

Formative Evaluation of Interaction Math

Summative Evaluation of Interaction Math

Third-party summative evaluation of the proposed Interaction Math project will be conducted by researchers at the University of Wisconsin-Madison's Learning through Evaluation, Adaptation, and Dissemination (LEAD) Center. The LEAD Center has assisted numerous principal investigators on the national and local level in assessing the impacts of their educational reform and outreach efforts and provided empirically-grounded guidelines for their improvement. Alexander was chosen to evaluate the impact and effectiveness of the proposed project because she has extensive experience in evaluating K-12 programs that are designed to increase interest in the fields of science, technology, engineering, and mathematics (STEM), and in particular to recruit and retain women and underrepresented minorities into these fields. Alexander will be assisted by LEAD Researcher, Katherine Acosta who is experienced working with underrepresented groups. As the official evaluator for the Education, Outreach, and Training (EOT) programs of the NSF-funded National Partnership for Advanced Computational Infrastructure (NPACI), LEAD has extensive experience assessing the impact of initiatives that involve educational technology in informal and formal educational settings.

The goal of the proposed summative evaluation is to assess Interaction Math's success in meeting its overarching goal of providing the nation's 3rd-12th grade learners, including those within underrepresented groups, rich, collaborative opportunities for learning mathematics.

D. Current and Prior Funding

Even though the proposed collaborative project builds on the results of several successful NSF-funded projects conducted by the PIs, it distinctively propels the Math Forum beyond any prior accomplishments. Previous and current NSF funding has allowed our project team to develop a strong capacity for this project in four key areas: building online learning communities, mathematics education technology support, online collaborative learning research, and informal learning environments.

1. The Math Forum, *REC-9618223*, \$971,300, *March 1999 to February 29, 2000* The Math Forum represents the most successful building of learning community for mathematics on the Internet.

2. MathDL, *NSDL Award Number 0085861* \$856,257, *September 2000-2005*, MathDL is an undergraduate-level digital library, a joint project between the MAA and the Math Forum. The MathDL and previous projects have given the Math Forum considerable experience constructing libraries and supporting technologies, such as metadata for the NSF digital library initiative. In addition, numerous Forum staff members have contributed to NSDL activities, meetings and working groups. The Math Forum was a founding member of the SMETE Open Federation, the largest identifiable user base for the National STEM Education Digital Library.

4. ESCOT (Educational Software Components of Tomorrow), *REC Award Number 9804930* was a test-bed for the integration of innovative technology in middle school mathematics. The Math Forum, working with SRI and other partners, developed team-based approaches that produced math tools for integration into the Problems of the Week.

5. The Math Forum Online Mentoring Project *DUE Award Number 0127516* is developing a guide to enable professors to integrate online mentoring experiences into their mathematics and mathematics education courses. Pre-service teachers in these

courses mentor students submitting their solutions to the Math Forum's Problems of the Week. The results of this project will be used to train mentors for the Technology Problem of the Week (tPOWs), part of a new NSDL funded digital library of mathematics software.

6. Catalyzing & Nurturing Online Workgroups to Power Virtual Learning Communities. *REC Award Number 0325447* September 1, 2003-August 31, 2008, \$2,299,978 This project is researching the following: How can one catalyze the formation of online workgroups? If there are a couple thousand users logged into the Math Forum, how can you automatically be put in touch with an optimal selection of 4 to 6 of those people whose interests and abilities best complement yours? Once formed, how can your group be nurtured with online tools, processes, structures and mentoring to maximize group success and collaborative learning? How can networks of different kinds of small groups contribute to the vitality of a larger community?

F. Dissemination and Sustainability

Because of the high visibility of the Math Forum website, dissemination will be a strength of **Interaction Math**. In addition to integration with The Math Forum website and search, Interaction Math will be featured prominently in the most popular services such as Ask Dr. Math and on the Problems of the Week pages. Further, The Math Forum is part of the NSDL and will be able to add Interaction Math into that wider context. The Math Forum Newsletter will distribute Interaction Math information to thousands of readers. Math Forum personnel will include information about Interaction Math in its presentations at mathematics and technology conferences (approximately 12 per year.)

As always, how to sustain the program beyond NSF funding is a real problem that will be addressed throughout the funding period. The Math Forum has been highly successful over the years in this regard. For example, the Problems of the Week program is partially sustained by subscription services **Five years of funding and careful system-wide programming will allow us to** develop a solid foundation, one which will allow further work to be practically self-sustaining. It will allow us to build up

- A data-base of high-quality, tested problem-solving activities to a sufficient number so that they can be re-cycled indefinitely with only minor modification,
- A national corps of trained volunteers that will help recruit and train others through an online automated training system, and
- A robust web-space that is programmed for low-maintenance.

After development, the program should be an ideal venue for corporate and/or private sponsorship which the program management will seek.

G. Conclusion: Just ten years ago few would have imagined the rich informal science resources on the web today, and we can only dream of where the web will be ten years from today. We believe that Interaction Math has the potential to help us to realize those dreams, adding a collaborative dimension that advances the capacity of the Internet to educate the public about science.