THE MATH TOOLS PROJECT

collection track

The use of handheld devices and computers in schools is becoming widespread and of growing affordability. Its educational power lies in supporting topics previously difficult to approach and in developing conceptual understanding through visualization, manipulation and exploration, while minimizing the demands of calculations.

The Math Tools project will create a digital library of mathematical software critical to the learning of school mathematics, including software for handheld devices, small interactive web-based tools such as applets, and other computer software. Beginning with knowledge of major software collections, a library will be rapidly amassed that features the most promising material. The library will continue to grow as critical mass and publicity attract submissions, along with the results of strategies for generating content from user interactions. The benefits of these technologies will be promoted by capitalizing on the Math Forum's large and active community. In collaboration with SRI, Key Curriculum Press, Texas Instruments, Shodor Foundation, and Utah State's NLVM team, this project will:

- catalog the math tools so that teachers, students and other users can easily find which ones fit their needs;
- present the tools using content strand portals for grades K-7 and course subject portals for grades 8-Calculus;
- provide mechanisms to help teachers and students learn to utilize the technology through such means as integration into the Forum's Problems of the Week, facilitated discussions groups, and manufacturer assistance;
- develop communities of users helping each other;
- construct a library of reviewed and relevant math education research on technology in learning mathematics;
- strive to get teachers and software developers working together for the production of better tools through such means as summer workshops and online activities.

This project will meet the need for a broad library of reviewed technology tools, augmented to include education research articles on this topic. It will also offer much needed support for teacher use of math tools, feedback for developers producing software meeting teacher needs, and fruitful interaction for researchers of educational technology. The activities of the project will aim for a largely self-sustaining user base by attracting a variety of users, including them in the formation of the community, and providing a wide-range of opportunities for involvement.

The Math Tools Project

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Results From Prior Support

The Math Forum, REC-9618223, $971,300, March 1999 to February 29, 2000

The Math Forum is arguably the most widely used math education site on the Internet (search for "math" on Google.) It began in January of 1996 as a proof-of-concept grant from the NSF to extend the work of the Geometry Forum into other areas of mathematics and to investigate the viability of a virtual center for mathematics education on the Internet. The Math Forum has developed a vast Web site [1] of over 925,035 learning resources and it receives over 650,000 visitors a month, with mentored user services such as Ask Dr. Math, for students of all ages, Problems of the Week services for grades 3-12, and Teacher2Teacher for discussions of pedagogy.

The Math Forum's home page allows browsing and searching the Internet Mathematics Library of over 8600 annotated entries of hand-selected resources. The cataloguing features are based on American Mathematical Society categories, and are enhanced by recommendations of the American Mathematics Metadata Task Force [2].

The Math Forum provides many ways for people to interact with one another, with different points of access for people of varied strengths, needs, and interests. Community building is an important part of Forum activities and has formed the basis of much of the content development on the site. The Math Forum represents a vision about the possibilities for an Internet community that extends the collegiality found in schools, classrooms, or the workplace. Evaluation of the Forum is used in program design, development, and facilitation, and provides an assessment of impact.

Publications:
Virtual communities [3, 4, 5], Problems of the Week [6, 7], geometry interactions [8]

Other Related Work

The goals of the JOMA Applet Project, DLI-2 Award Number 9980185, were to 1) search the Web an other resources to locate and collect applets and similar programs developed by the mathematics research and teaching communities, 2) review and test these systematically, and 3) to make them easily accessible to undergraduate faculty and students. JOMA, *the Journal of Online Mathematics and its Applications,* is published by the Mathematical Association of America. This project was the basis for MathDL an undergraduate-level digital library, NSDL Award Number 0085861, a joint project between the MAA and the Math Forum, which is developing the technical infrastructure.

These projects have given us 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 [9], the largest identifiable user base for the National STEM Education Digital Library.

ESCOT (Educational Software Components of Tomorrow), REC Award Number 9804930, was a testbed for the integration of innovative technology in middle school mathematics [10]. The Math Forum, working with SRI and other partners, hosted summer workshops for teachers and developers that produced math tools for integration into our Problems of the Week. Math Forum evaluators studied the effect of these POWs on student learning [11].

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. We expect to use the results of this project to train mentors for the Technology Problem of the Week (tPOWs) in the proposed project.

Need for Work

This is a crucial moment to begin this project. Technology tools should be playing an important role in student learning in mathematics [12 , 13, 14, 15, 16, 17]. Developing these tools is a growth area, with many new tools on the way (see below), yet it's difficult for teachers to find what they need, to know if it's any good, to coordinate across technologies and platforms, and to learn how to teach with it [18, 19, 20]. Through the Math Tools Project, the Math Forum and its partners will develop a digital library community where K-Calculus teachers and tool developers can begin to address these problems.

It is a time of great vigor and diversity in the production of technological tools for teaching mathematics. The landscape for computers has expanded from math education

software titles to small, interactive, web-based computer programs written in JavaScript, Java, and Flash, hereafter referred to collectively as *mathlets*. Similarly, while graphing calculators continue to improve in power and scope, many other handheld devices are poised to follow their lead, be they personal digital assistants (PDAs) such as Palm Pilot and Visor [21, 22, 23] or WIN CE products manufactured by Toshiba, Casio, Sharp, and Brainium [24]. The burgeoning industry of technological tools poses many opportunities—and many decisions—for math students, teachers, administrators, and parents.

The Math Tools Project will address problems faced by teachers utilizing mathematics teaching tools, by the students who use them, by the programmers who develop them, by the parents who would support their children, and by school administrators who must make choices.

1. No "smart" repository of technology tools exists.
Tools are hard to find because they are scattered across isolated repositories. Even when they do locate them, teachers often face prohibitive software licensing or professional training.

2. It's not easy to gauge the quality of a technology tool.
Existing digital libraries with mathematics content target colleges and universities, where the incentive of academic references drives publication and peer review. This, coupled with high standards, has mostly resulted in small collections of high quality material for post-secondary education [25]. Tools for pre-college classrooms do not enjoy such attention and, consequently, lack reliable reviews, user comments, and ratings.

3. It's hard to identify appropriate tools for classroom implementation.
Because teachers fail to find tools, it is difficult to compare their pedagogical value, fit to curriculum, and ease of use.

4. Technical problems abound for teachers, students, and developers alike.
The multiplicity of software tools and technology platforms available presents a cacophonous barrier to both the primary and secondary teaching communities. Further, there is no process for integrating one tool collection with another, or integrating access across tool collections. Some leaders are calling for networked handheld devices instead of computers for schools [26] creating new challenges for teachers and administrators.

5. Poor feedback mechanisms between the developers who produce tools and the teachers who need and implement them are the norm, not the exception.
When left to their own devices, professional developers can produce tools unsuitable for student learning. Our own experience [27, 11] and that of others strongly indicate that developers benefit greatly when teachers contribute to the design process from the outset [28, 29].

6. The research literature that might guide developers and teachers is not easy to find or search.

While much is being written about the use of new technology tools and the impacts they have on student learning, there is no convenient single resource available to teachers and developers

7. Technology tool users often lack experienced colleagues to help them expand their horizons.

From individuals to school systems, would-be purchasers do not have a comprehensive collection to visit to obtain some perspective of their choices of hardware or software. For example, while graphing calculators are now programmable and good material exists (see, e.g., [30] for hundreds of programs), usage usually remains limited to the programs that arrive on the device. Teachers need a pedagogical framework to think of the value of graphing calculators [31], as they do with the learning tool nature of the machine.

Step 1: Creating the Repository—Collecting and Reviewing Tools

Collecting Tools:

Our goal is to collect and review all the important high quality technology tools used in mathematics education, K - Calculus: software for graphing calculators, PDAs such as Palm Pilots, and other handhelds; small computer programs ("mathlets"); medium sized packages (Geometer's Sketchpad, etc.); and very large "computer algebra systems" (Maple, Mathematica, etc.). (Some of the medium and large programs now make it possible to construct easier to use project-oriented "sketches" or "notebooks," further enriching the situation.) Our strategy is to first incorporate large collections where quality tools exist, collaborate with manufacturers for "emerging technologies" to learn of new developments, and work with a publisher to make sure we cover the major commercial products. In this fashion we will rapidly build up a sufficiently large collection of reviewed tools to draw teachers to the site (see *Step 2: Driving Use* for a discussion of how we will attract users). We will also engage the developer community (*ibid*) by addressing technical barriers. Then, as teachers nominate their favorite tools, and developers learn from each other and become aware of the opportunities for ideas and teacher collaboration furnished by the community, their interactions will help expand and enrich the collection.

Texas Instrument has by far the largest collection [32] of material available for programmable calculators. As mentioned earlier, Palm Pilot, Visor and WIN CE products are bursting onto the scene. One of our partners, SRI, will help us track these newer platforms as tools develop for them (further discussed in the *Sustainability* section).

If you know where to look, there are many mathlets on the Web. Two of our partners are highly regarded for the quality of their applet production, the Shodor Foundation [33] and Utah State's National Library of Virtual Manipulatives [34]. Each has a collection of around 100 tools. The Math Forum also has at least 500 other appropriate tools that students have collected, tested, and screened as part of the JOMA project.

The Shodor Foundation in making their collection available to us will develop resources to help existing high-quality collections expose their metadata and become accessible to the many users of NSDL. More particularly, they will develop a community object toolset that will enable collections to expose their existing materials to the digital libraries while facilitating the building of new tools. This is going beyond merely tagging existing applets but would be tested by accomplishing this. See their subcontract for more information.

We will collect and review regular commercial computer programs larger than mathlets, and will work with Key Curriculum Press to assure that we develop a solution appropriate for software publishers and that we include all the major programs.

It should be noted that by "collecting" we will in general have only a link to the actual tool. When possible we will house the actual tool itself (even the source code) since this avoids unexpected changes in the tool or link.

Reviewing—Assuring quality in the collection:
We will find tools that hold pedagogical promise, function well on at least some common platforms, and provide correct results. We will work early on with teachers, students, online library staff, and developers to refine that informal definition of quality as usage, feedback, and review instruct us (see our descriptions of the JOMA and ESCOT projects, above). Existing quality standards by digital libraries such as Eisenhower National Clearinghouse, Merlot, iLumina, and JOMA will be carefully considered.

As we have done with the Internet Mathematics Library and are formalizing in the Online Mentoring Project, we will train and oversee knowledgeable persons to review the math tools. This approach appears to be much faster than the review process currently in use by other digital libraries, and has resulted in our large and trusted collection. We will invite applications from contacts we already have – Math Forum visitors and associates, Texas Instrument's T^3 instructors, and College Board workshops for 400 AP teachers. We will also look for interested reviewers through NCTM and other journals and through websites. Reviewers will comment on expected pedagogical value, usability and technical issues, accuracy and insight for chosen math content, and platforms for which the tool works. Reviewers will also give tools an overall rating. Users will be able to rate tools in the style of Amazon.com book reviews.

Public review and discussion will also include: implementation experience and advice, effectiveness for given purpose and context, pointers to related resources and research, etc. Each tool will have its own discussion area and bug report list. When users report that a tool doesn't run on their platform, we will corroborate the report and supplement the review accordingly. Discussions will give teachers and developers a place to converse about pedagogical uses and potential improvements.

Literature Reviews:
George Reese of University of Illinois Urbana-Champagne (see attached CV) will coordinate reviewing the literature of research on the use of technology in math education. He (and others as the project evolves) will give articles brief capsule reviews

and ratings, paying particular attention to their relevance to teachers and developers. They will also nominate articles to feature in the public discussions, advertise them on the site in the style of slashdot.org, and facilitate the ensuing conversation, with a special eye toward helping teachers participate profitably in the discourse.

Building a Web Site to Get People to the Right Tools

Design Principles: The web site will be designed so that users can rapidly and conveniently get to the math tools that interest them. For example, users will be able to restrict their viewing to appropriate platforms.

Based on our previous digital library activities (see Result of Previous Work, above) and on what we have learned from the work of others, we will

- design simple pages that load fast, without clutter
- elicit and act on user feedback and evaluation
- use graphics judiciously, such as to provide a thumbnail image of a math tool screen (as seen for example in the venerable Educational Object Economy Library [35]).

Special Pages*:* The site's home page will highlight a few items of general interest, such as our monthly education article discussion, discussions of general interest taking place elsewhere on the site, and occasions for groups to work together (e.g. teachers and developers or teachers developing lesson plans on a particular topic). There will also be links to more specialized entry points for browsing.

The main entry points to the Math Tools digital library for teachers will be via pages corresponding to typical K–Calculus courses, and by content strand for the earlier years:

Elementary Math (content strand portal)
Number and Operations, Geometry, Data and Probability, Patterns and Relationships (Algebra), Measurement.

High School Math (typical course names)
Algebra 1, Geometry, Algebra 2, Trig/Pre-Calculus, Calculus, Prob and Stat, Discrete Math, AP Calculus, AP Prob and Stat

Developers will have an entry point to take them directly to information about programming for various platforms, sharable software development tools, and review comments from teachers about the effectiveness of the tools.

The entry point for students will provide links to resources such as Ask Dr. Math, tools related to material they are studying, and discussions. The parent's entry point will also contain discussion groups concerned with the meaning of technology changes in mathematics education, and one about special problems of homeschoolers.

Math Forum Services: The proposed software library will integrate with activities elsewhere on the Math Forum site, resulting in a rapid influx of users.

tPOWs: Simply having wonderful tools available will not be enough to help many teachers who are unfamiliar with their pedagogic use. We will embed them in a context where their use is natural, valuable, and effortless: into our own suite of Problems of the Week, as *Technology Problems of the Week* (tPOWs), where technology plays a useful role. This proved to be a successful approach with the ESCOT project (see above). We will recruit a group of "t-problemists" as we search for facilitators, reviewers, and other ways for users to be involved with the project. The problemists will be trained, supervised, and directed by our Problem of the Week personnel.

The Shodor Foundation will participate in the proposed problem of the week activities (see subcontract). They have a good start on these with a number of open-ended problems and they develop problems that don't simply have "an answer" but require the students to make and defend observations about the nature of patterns and phenomena.

Our summer workshops (see below) will begin with teachers finding good candidates for tPOWs and continue as the teachers collaborate with developers to produce or modify tools to fit the needs of the problem. Their collaboration will drive adaptation and innovation: once we have a tPOW for one platform, if a similar tool exists on another platform, the problem can be simply reused with the new platform (we will identify for programmer attention those platforms lacking an appropriate tool). Not only will our tPOWs be reusable across platforms, some of the more general purpose and powerful programs will be reusable as well, and be suitable in many tPOWS. (Reusability is considered a very powerful idea in the CS world [36, 37, 38, 39, 40, 41] and we expect its application here to help make the tPOW concept viable).

We will build up a database of good problems for which a technology tool would be a valuable or even necessary asset, thereby putting the horse before the cart. The database will be constructed from t-problemist ideas, summer workshops, and general submissions. This database will show developers pedagogically important areas in need of new tools, and thereby stimulate their creation. Our developer areas will contain relevant lists of specifications for these tools.

Search Engine: The Math Forum will build on the experience we have had configuring and refining our site search which identifies common searches and starting points, as well as common spelling errors (it is especially good at spelling Pythagoris). We expect to participate in the NSDL drive toward federated searching, so that our materials will be visible from other sites.

This project will also benefit from our other research on enhancing user navigation, and we are studying user ability to learn from archived resources with strategies that combine functions such as user tracking and registration, case-based reasoning, ontology development, etc. See *Step 2*, below.

User Services

User Support: For each course and content strand, we will provide a facilitator who helps users learn how to use the technology and the resources. Questions may be addressed by the facilitator, other users, and, when appropriate, by the manufacturers of handheld devices (with whom we are developing special arrangements; see the letter of support from Texas Instruments). We will look to the pedagogical needs of users, providing and facilitating discussion groups in line with the Math Forum's Teacher2Teacher project [42].

For further information on user involvement, using profiling for user support, and user discussion support see *Step 2*.

Developer Support: In the burgeoning area of small tool development, we pointed out above that one of the keys to building quality material is to connect software developers to teachers. We have observed that at the college level, mathlet developers are quite interested in working together and sharing information (browse through the Developer's Area of JOMA [43]). For handheld programmers, we will work closely with the manufacturers, who have an interest in seeing good material for their products. A Test Area will host beta versions of tools for constructive comments on the technology and pedagogy.

Two key software notions for efficiently and effectively developing software are reusability and interoperability (see above). These *should* play an important role for our tool developers, but since many have a background in teaching mathematics rather than in computer science, they may lack an appreciation of these ideas. Jeremy Roschelle, whose ESCOT project was in part devoted to these ideas [44], will work with developers on these crucial concepts. In particular, he will customize the evaluation framework for reuse and interoperability that he developed for the JOMA collection [45] to the Math Tools Digital Library. He will also interview key contributors and users about these issues, perform independent technical analysis, develop recommendations, and report to our developer community. Exemplary tools will be highlighted for developers. See the SRI subcontract.

We will work with the National Library of Virtual Manipulatives (hereafter NLVM) at Utah State who have developed techniques to allow teachers to save applet states and associate them with activities [46]. These features utilize a cross-browser XML-based approach for which they will share source code, examples, and documentation. We will develop standards and provide general software tools so that other developers will be able to include these features as part of their applets. Another goal is to provide teachers with the ability to configure an applet in exactly the state desired for use in a lesson plan or activity. See the subcontract for further information.

AP Courses: We will work with the College Board to make Advanced Placement course areas particularly appropriate to the needs of the AP community. For, the method of instruction and use of technology may be different in these courses than in other courses [47]. Moreover, graphing calculators are now heavily tied into AP work, so our AP consultant will also advise us on graphing calculators. AP Stat students are expected to be familiar with computer output from software.

Step 2: Driving Use

In order for the Math Tools site to become the center of an active, viable community, people need to a) know about it, b) find what they want when they get there, c) believe that the information they get is reliable, d) understand that the possibilities are rich, but not too complicated, e) make it part of their work and regular activity, and f) feel invested in its creation. The Math Forum has experience meeting these needs through its own Web site. To accomplish these goals for the Math Tools site, we will implement similar strategies as we have used before, but also develop new methods for engaging users in better discussions and for more effectively understanding user activity and preferences.

Attracting Users

Through the evaluation of the Math Forum project and work with other Web sites, we have found that the following categories of people are common across sites.

> *First-time visitors:* Every Web site gets a stream of first-time visitors. They are minimally involved, but have potential for becoming more involved if they find what they want and find reasons to visit again.
> *Loyal readers/visitors*: A portion of first-time visitors will find the site useful or interesting and will come back repeatedly for discussion or new content.
> *Contributors:* A portion of loyal readers will be interested in contributing their thoughts and opinions, asking questions, and helping to develop new content or tools.

To attract first-time visitors, and to provide material and services that will assist as many people as possible to become loyal readers and contributors, we will:

- promote Math Tools on the Math Forum site and providing links wherever appropriate.
- contact partners, collaborators, and supporters to mention Math Tools on their mailing lists and Web sites.
- write press releases and articles in NCTM and other journals and newsletters.
- present demonstrations and discussions at regional NCTM conferences and other venues.
- work with NCTM, ENC, PCMI and other colleagues who run workshops for teachers to promote the use of Math Tools.
- make the benefits of increased participation visible and compelling.

Encouraging Discussions

Virtually all publicly-readable discussions have far more lurkers than posters. Successful discussions have a culture of encouraging people to participate.

Each course and content strand will have a facilitator to monitor all of the general discussions and the tool-specific discussions. Through upgrades to current Math Forum discussion software, the facilitators will have tools to highlight posts, flag time-sensitive messages, delete spam and flames, and change threads. They will be given access to our user database (see below) in order to respond and solicit participation more effectively.

Facilitators will use captivating quotes from discussions and articles, as is done on the Slashdot.org programmer site. As the discussions and our user profiling develop, users will be given the capability to annotate existing posts, mark them for easy revisitation, and privately identify people they admire or wish to avoid. With Professor James Levin of the University of Illinois, Urbana-Champagne serving as consultant (see attached CV), we will pool their comments and do cluster analysis to obtain community rankings.

Using User Profiling

To better meet the needs of our growing community, we will develop a user profiling system that connects types of visitors to comments and ratings. We will also track users with cookies to follow user movement through the site and time spent in various areas. These tools will also aid the discussion facilitators in their goal of creating rich discussions, and help us build profiles of individual users in order to customize their pages. 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 tools to use.

We will work with Shodor (see subcontract) to explore an "Amazon.com" model for materials delivery that will provide feedback to users, perhaps in the form of "users who liked this activity, also liked this other one." Together we will conduct experiments with behavior tracking in the use of the tools to determine whether this service improves library utilization.

Our privacy policy and use of student information will be based on our current policy [48] which appears at the bottom of our POW pages. 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.

Engaging Teachers and Developers in the Community

Teachers and lesson plans: The NLVM subcontract staff will continue to collaborate with Mimi Recker of the Instructional Architect project at Utah State (NSF, DUE-0085855) to bring to teachers the ability to insert math tools into web-based math lesson plans. We will extend these tools and materials so that they are available and applicable to all Math Tools. Teachers will be able to go to our site, find a math lesson, use and evaluate it and give it a rating. They will be able to modify it or create their own lesson and save it in the library for use by other teachers and students.

Summer Workshops for teachers and developers: Math Forum summer workshops and institutes in the past have led to valuable collaborations, content development, and a strengthening of the growing community. Each summer throughout the Math Tools project, we will hold a workshop for 10-12 teachers and 3-5 developers, extending the ideas of the workshops we held with the ESCOT project, which showed that such design teams can play a crucial role in the construction of tools of high pedagogical quality. The teachers will arrive first to work together on constructing problems that could benefit from the use of technology tools in a natural and integrated way. If the appropriate tool exists, we will incorporate it and produce an interactive tPOW. This process will also help us identify tools that need to be designed. When the developers arrive, we will form design teams of developers, teachers, and other technical staff. The design teams will spend the remainder of the workshop creating new tools or modifying old tools to fit the problems. They will continue collaborating via email afterward until their projects are completed.

tPOWs: The summer workshops will contribute considerably to creating tPOWs (Technology Problems of the Week), which will in turn strengthen site usage. Teachers who are uncertain about using a new mathlet or tool in their classrooms will have opportunities to begin experimenting with tools that are already placed in the context of rich math problems.

The Math Forum has never had a need to drive usage for the Problems of the Week—there has always been more work than our mentors can handle comfortably. The Online Mentoring Project, described above, will speed the training of teachers, including in-service and pre-service, for this new project.

Assessment via Handhelds*:* One exciting idea that is coming forth is for teachers to use PDAs (Palm Pilot, Visor, etc.) to collect assessment data on students as they work on math projects. Our tools will provide good resources for math projects and we envision teachers helping their students and at the same time entering relevant assessment data in their PDA. SRI is developing this kind of software for science and Carol Midgett at the University of North Carolina, Wilmington, is working on the beginnings of a similar project for mathematics via a PT3 grant. We will keep our users aware as these tools develop by consulting with Carol Midgett along with Jeremy Roschelle and Phil Vahey of SRI. This is an example of how we plan to engage our readers in new and important ideas and projects.

Sustainability

Migrating from facilitator-oriented beginnings to user-moderated discussions at the end
We singled out three types of users: first-time visitors, loyal readers, and contributors. To these we now add a fourth type: facilitators. As the community becomes large and successful, a small proportion of contributors will become so deeply involved that they will want to help manage it. They will be willing to actively publicize, go out of their way to answer questions, spontaneously compile FAQs, and so on. At the beginning of the project, facilitators will be recruited directly, as outlined below. Our long-term goal, however, is to achieve a spontaneously self-organizing community.

We expect to deliberately build up the community to the point where it can become self-sustaining—or at least to the point where it needs very little staff time to maintain. We have developed communities that are low maintenance, such as our "math doctors" for Ask Dr. Math. Realistically, we have to expect that the Math Tools project will require some administration and infusions. The Math Forum is committed to finding funds to support these through corporate sponsorships, gifts and grants, and general operating budget.

The area that is likely to see the most growth and to change in unpredictable ways is handheld hardware and programming environments. As our letters of support demonstrate, our proposal has elicited considerable interest and assistance from the manufacturers. We also will have industry liaison assistance by Jeremy Roschelle and Phil Vahey (see SRI subcontract) that will prepare us to meet circumstances with even more support, especially as we demonstrate our value to the industry. In particular, SRI will help us:

- communicate the NSDL Math Tools opportunity to Palm, TI, Intel, ImagiWorks, Key Curriculum and other companies,
- understand technical and business concerns that the NSDL initiative presents to participating companies,
- broker industry participation in NSDL with respect to Math Tools by talking to decision-makers and Web site technical leads at such companies, and connecting them with appropriate decision-makers and technical leads within NSDL.

Much as we expect developers to contribute new math tools so do we expect researchers interested in the impact of technology in math education to submit us their articles, allowing us to continue the growth of a valuable library for the research community and other users as well. This will also stimulate greater recruitment of reviewers and discussion facilitators.

Work Plan: Collection Activities

Before Official Proposal Approval

- Finalize approval to use major collections (TI, Shodor, Utah State).
- Find a few high-quality reviewers through personal contacts, College Board workshops, TI, etc.

YEAR 1*:*
Spring Semester, 2003

- Forum staff begins developing Audition Tool and Reviewer Guide, working with first reviewers.
- Reviewers begin reviewing and also working with staff to refine Audition Tool and Reviewer Guide.
- George Reese begins research article reviews.

- Identify workshops where we can show our material, find teachers, get professional development providers involved.
- Send notices to appear in journals, web sites, timed for announcement of pilot site.

April, 2003 NCTM meeting

- Launch pilot version of site, publicize site, look for reviewers.
- Begin campaign for teachers to send tool nominations, user reviews.

Summer, 2003

- Hold first Summer Workshop for teachers and developers.
- Use Audition Tool and Reviewer Guide to develop corps of reviewers by mid-summer.

Fall, 2003and throughout rest of project

- Continue with review activities already begun and to recruit new reviewers.

YEAR 2: 2004

April, 2004 NCTM meeting

- Official launch of Math Tools site. Target date to finish searching for and reviewing main collection of tools.

Summer, 2004

- Concentrate on community building aspects of site and teacher-developer work.
- Hold second Summer Workshop for teachers and developers.

Fall semester, 2004

- Make presentations at NCTM regional and other meetings.
- Continue reviewing, recruiting, and finding new tools.

Work Plan: User Activities

Before Official Proposal Approval

- Begin informal search for facilitators to lead the 5 content strands, 9 courses, and the overarching community.
- Work with handheld manufacturers to find appropriate facilitators and leaders.
- Develop agreements with manufacturers to provide special help desks where users can go with technical problems.
- Use personal contacts to find computer software developers to act as facilitators and leaders. Aim for experts in applets, java script, Flash.

YEAR 1:

Spring Semester, 2003

- Continue recruiting facilitators, also tPOW constructors, tT2T resource persons, and other group leaders.
- Work with facilitators to accommodate various teacher categories:
    - those new to technology

    - more experienced technologists
    - pre-service
    - in-service.
- Look for professional development workshops and other venues where we can show our material and recruit leaders.
- Plan the construction of tPOWs with appropriate Forum staff and problemists.
- Start Developer's Page and pages for each handheld and relevant programming language. Look for situations where developers can share programming tools.
- Start on student and parent portals.
- Develop pilot version of overall site.

April, 2003
- Demonstrate pilot site and use the NCTM meeting to further our aims, above.
- At NCTM meeting, T^3, ICTCM, etc. work to get developer and design team discussion and demos.
- Begin monthly discussion of research articles.
- Finish startup version of student and parent portals before summer.

Summer, 2003
- Revise pilot site on the basis of teacher and other feedback.

Fall Semester, 2003 and throughout rest of project
- Give talks, demos, workshops at NCTM regional meetings.
- Continue to recruit facilitators, revise site, and engage users in community.

YEAR 2: 2004
Spring, 2004
- Work toward launch of official site.

April, 2004
- Officially launch site at time of NCTM Annual. The basic collection will be in place.
- Concentrate on community building and teacher-developer work.
- Have developer and design team discussions and demos for NCTM meeting.

Summer, 2004 and throughout rest of project
- Revise portals based on feedback.
- Work with professional development workshops, teacher workshops, (including our own) to use Math Tools.
- Continue to recruit facilitators, revise site, and engage users in community.

Evaluation

The evaluation of the Math Tools project will be composed of four parts,
1) formative evaluation to guide the development of the Tools Web site and its ability to attract users,

2) questionnaire to assess how the implementation of the Web site is being received by users,
3) interviews with teachers and developers in the summer tPOW workshops as well as interviews with a sample of teachers about the usefulness of the tPOWs and the Math Tools Web site, and
4) assessment of students' mathematical thinking using the tools developed in the tPOW workshops.

1) *Formative evaluation* will utilize the following collaborative process developed at the Math Forum by K. Ann Renninger and Wesley Shumar. Math Forum staff will have a focus group meeting every six months throughout the project. The purpose of the focus groups will be to review the site design, the best way to effectively meet user needs, how design can serve to encourage usage of tools and more learning interactions. The outcome of the sessions will be a set of measurable short-term goals and a set of longer term goals. In addition, questions about user needs will be drafted for the user questionnaires and the teacher interviews. After the first meeting, each focus group will assess progress on short-term goals and readjust long-term goals.

2) An *online questionnaire* will be developed specifically for the Math Tools Web site. The questionnaire will be mounted online for a two-week period and ask users to volunteer to respond. The questionnaire will address questions about the value of the tool, the ease of usage, the ability to find tools and navigate the site, the process of integrating tools into lessons and learning processes. Data from the questionnaires will be analyzed and presented back to the next focus group meeting.

3) The *interview project* will involve two separate but related interview samples. The first will be a random sample of teachers who agree to use the Math Tools site and integrate tools into their classes. These teachers will be interviewed to get a more detailed, personal look at the problems and successes they face when attempting to integrate these technologies into their classes. It will also offer insight into the value of the interactive aspects of the site for their teaching and their own learning.

The second interview sample will be drawn from the teachers and developers at the tPOW workshops. These teachers and developers will be interviewed in order to further assess the ways the creation of intentional online community can foster improved work in the development of tools for math education. The Math Forum already has considerable experience in this area through the ESCOT POW workshops [49].

4) *Assessment of student learning* through change in mathematical thinking will be done following the work at the Math Forum on the ESCOT POW and the other POW services [50]. Analysis of students' mathematical thinking, approach to the problem, and guessing strategy in work with the EPOWs will be studied. Independent variables included students' interest for mathematics, feelings of self-efficacy as a learner of mathematics, competence, standardized achievement scores, and gender

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