### "*ITR: Catalyzing & Nurturing Online Workgroups to Power Virtual Learning Communities*"

## Project Description



## 1. Vision

It is January 2009 and the proposed project has just ended. Tanja is home schooled in up-state New York because of a physical disability; Sarah lives on a remote Navaho reservation; Damir attends school in Croatia. They each read the same "collaborative Problem of the Month" (cPOM) on the Math Forum (MF) website and became interested in it. The problem is to specify a general equation or algorithm for saying how many squares a straight line segment on graph paper will go through, given the coordinates of the line. Based on previous visits of Tanja, Sarah and Damir individually, the new MF website software determines that they have a mix of interests and skill levels that might work well in a small group solving this problem together. MF invites them and a couple more students to work together. Tanja, Sarah and Damir respond and find themselves together in the Math Forum's online collaboration environment. This Internet environment helps them to coalesce into an on-going group to work on this problem; to communicate both synchronously and asynchronously; to represent the problem and its features; to store, reflect upon and reorganize their collaborative ideas; to negotiate a group response to the problem; to document how they arrived at their response; to submit their response to MF; to receive immediate feedback; and to decide if they want to continue collaborating.

Sandra, a teacher who has used MF with her math classes for years, reads the solution submitted by Tanja, Sarah and Damir and starts to think about a related problem, which she posts to a MF discussion. A number of other teachers respond with interest, and the MF website software invites them to work together with a MF staff person to develop this idea into a publishable cPOM. They use the MF environment to collaborate, reviewing several of the responses to the previous cPOM and eventually releasing a new problem that asks how many regions are formed by connecting N points on a circle to each other.

MF staff notice that a number of recent cPOMs involve drawing simple line figures and counting features such as vertices and regions. They request the MF environment to set up a work group with several of their technical collaborators around the world who might be available and appropriate. Together, the people who respond form a group, specify user requirements, brainstorm designs, develop prototypes, conduct user testing and develop a new tool for the MF. This tool allows student groups to collaboratively sketch representations that help them visualize and communicate about features of 2D drawings.

Back to the present. This Project will explore the potential of the Internet to bring together small groups of people like the three groups described above, who share interests and skills that might allow them to learn collaboratively and to build knowledge together. By the start of the grant period, MF is projected to be serving over a million students per month. This means that by the end of the grant period it will be common to have over a thousand math-oriented people accessing MF at the same time during peak usage. This is a rich pool for forming compatible small groups at various levels of mathematical interest for collaborative learning.

It is clear from current learning theory that collaborative learning is an effective way for many people to learn, particularly people who tend to be left behind in classroom situations (Johnson & Johnson, 1989). It is also clear from experience that an approach that emphasizes discourse and inter-personal interaction helps to build deep understanding of mathematical principles – rather than simply exercising rote memorization – in keeping with contemporary pedagogical priorities (NCTM, 2000; Renninger & Shumar, 2002b). What is not clear is whether software can be developed to match people who are using the Internet based on their known interests and skills, or whether these people can be formed into effective groups for collaborative learning. There has been almost no relevant research about online group formation (rare exceptions include: Haake et al., 2003; Wessner et al., 2002; Wessner & Pfister, 2001). Even in face-to-face settings, there are many open questions about how to form effective learning groups and then how to structure their collaborative tasks (Stahl, 2000b). Finally, only rather primitive software is available to support collaborative knowledge building (Stahl, 2002d). This project will explore the theoretical, technological and pedagogical issues and will systematically design, implement and assess an integrated approach to foster the building of mathematical knowledge in virtual groups.

## 2. Innovation & Significance

The long-heralded promise of the Internet was that people could not only access the whole world of information from any location, but also that they could meet people who shared their interests and could explore ideas together (Bush, 1945; Engelbart, 1995; Hiltz & Turoff, 1978; Rheingold, 1993). With the exponential growth and the specialization of the world's knowledge in mathematics and science, for instance, it is unlikely that someone with a particular momentary interest would happen to know many other people in their physical neighborhood with that interest at that time. Yet, there are currently few examples of technologies that fulfill this promise of the Internet and allow one to find and work with some of the many people who might share one's interest across the nation or around the world. This project proposes to develop such a technology and to demonstrate its effectiveness in the learning of school mathematics.

Of course, we see with Internet newsgroups, for instance, that people will struggle to engage in collaborative problem-solving even with primitive tools and haphazard opportunities for group formation. This Project hypothesizes that systematic support for building carefully balanced heterogeneous small groups will foster more effective collaborative learning, and that providing appropriate structure and scaffolding for the group interactions will further increase their effectiveness.

Information technology (IT) to date has transformed how individuals work and learn. The Internet has leveraged the productivity of desktop support by allowing individuals to communicate ideas (email, messaging, chat, newsgroups, video-conferencing) and to share information (websites, digital libraries, shared repositories). But there has been little progress toward supporting the intense interactions of spontaneous small group collaboration that builds shred knowledge. The motivation for this Project is that support for small group collaboration may yield the next major benefits of IT for working and learning. Progress in this direction may consist largely of adapting and packaging technologies that are now within reach – for the tough research and implementation issues are more social than purely technical. Careful, detailed, rigorous study is needed of particular technologies in specific social contexts. This Project will study alternative IT solution to catalyzing and nurturing several kinds of workgroups within the context of the MF virtual community.

The Math Forum (MF), started with NSF support, is an organization and mathematics website that offers a variety of services, primarily to students and teachers interested in topics of mathematics commonly encountered from kindergarten through calculus courses. It currently receives over 800,000 online visitors a month. Most of these are people who are solving mathematics problems on an individual basis. MF is interested in supporting more collaborative approaches to learning – not only for student visitors working on the popular Problems of the Week (POWs), but also for teachers developing curriculum and for people associated with MF who are developing new resources such as new POWs. MF would like to harness, extend and apply IT to foster and support the formation of small groups of people to explore topics in mathematics.

Computer support for collaborative learning (CSCL) is an established research field, offering technology, theory and pedagogy. Although there are comprehensive CSCL systems to support classroom learning (e.g., WebCT, Blackboard, Lotus LearningSpace, Knowledge Forum / CSILE, WISE / KEY, Synergeia / BSCL), these systems do not include support for the formation of small workgroups based on criteria of compatibility – even within classrooms, let alone in larger, more amorphous communities. The proposed project will support the formation and subsequent collaborative learning processes of a variety of specific types of small groups drawn from the MF community.

This project will approach group formation in a systematic way, developing theory, technology and pedagogy that are integrated together. The collaborative learning theory will describe the phases of group interaction, such as: group formation, task specification, brainstorming, proposals, negotiation and publication of results. These reflections will build not only on theoretical frameworks common in the CSCL literature, but specifically on past studies of the MF virtual community (e.g., Renninger & Shumar, 2002; Renninger et al., 1989). The computer support technology will provide a comprehensive environment within which virtual groups can successfully pass though these phases. It will be developed using best practices of user-centered human-computer interaction and extensive iterations of user testing within MF. The pedagogy will describe the nature of appropriate group membership criteria, problem characteristics and process facilitation. It will involve a reorganization of the usual MF process oriented to individual learning into one oriented to collaborative group learning, as described in the following paragraph.

The MF community can be described as a pyramid, with a broad base of individual first-time visitors, followed by successive layers of: loyal readers, contributors, facilitators and finally a small staff. While MF began in 1996 as a top-down, funded effort, its goal is to create a self-sustaining community where ideas, POWs, and activities flow up from the bottom. The formation of virtual groups will be a major means for achieving this, by encouraging and supporting people to move up the pyramid from occasional visitor to co-designer of MF services. In particular, groups will be formed at three levels in this project: (a) visitors/readers who want to solve collaborative POWs (cPOWs), (b) contributors/facilitators who formulate new cPOWs and (c) facilitators/staff who maintain and extend the MF technical infrastructure. (a) New problems will be offered that are suited to collaborative learning, stressing richer, more open-ended topics designed to foster discussion of deeper mathematical understanding. (b) These new cPOWs will be designed by groups formed of contributors, who will have access to an extensive digital library of past MF problems, math-related applets and studies of responses to previous problems. (c) Groups of facilitators, programmers and MF staff will form to maintain MF's mathDL and related services, including the production of new mathlets (programmable applets for computers and handhelds), in response to the needs of groups (a) and (b).

The project is designed to be highly iterative, so that the different aspects of the project can evolve in response to each other. The project starts on the basis of considerable experience with POWs solved by individuals – generally working within supportive communities of classrooms or MF mentoring, but without collaborative learning groups. The first year focuses on micro-analysis of this experience, incorporating previous studies of the MF virtual community, but clarifying the theoretical and pedagogical issues as well as the specific user requirements for the technology. In the second year, technological supports are gradually introduced to support group formation and knowledge building. An initial set of cPOWs that have been meanwhile adapted from old problems is used. In the third and fourth years, groups at all three levels are active; well-defined experiments and formative evaluations drive revision of the technologies and practices. In the final year, the project will observe the stable functioning of self-forming groups at all three levels and will evaluate the success of people finding compatible group partners and learning mathematics collaboratively. Logging of group interactions as well as MF hits will allow for careful quantitative and qualitative evaluation of the theory, technology and pedagogy.

## 3. Theory

Collaborative learning, as understood in this proposal, involves a focus on the group level of analysis. Of course, construction of knowledge by a group can also be seen as co-construction by the individuals in the group, and the building of knowledge by the group has direct implications for learning by the participants. However, it is also true that the group can produce knowledge that none of its members would have produced by themselves and it is true that, for instance, the meaning of things said in group discourse is defined by the group interaction itself rather than simply by ideas in the minds of individuals (Stahl, 2003c). Although this project will also be concerned with the learning of individual participants, its focus will be on the building of knowledge by small groups. This emphasis is consonant with theories from cognitive science, communication theory, anthropology, education and CSCL, such as situated action (Suchman, 1987), activity theory (Engeström, 1999), situated learning (Lave & Wenger, 1991), distributed cognition (Hutchins, 1996), etc.

Traditional learning theory assumes that learning happens entirely in the mind of the individual, it can be led or facilitated by a teacher, the content is to some extent irrelevant (in that one can learn anything) and that this is a primarily cognitive act. But advances in learning theory have led to very different assumptions about the learning process. First is the realization that learning is a constant and ongoing process. People are always learning whether it is part of some specific curriculum or not. As Dewey pointed out the purpose of teaching and education is not just to help students learn but to create opportunities for experiences that lead to productive forms of learning (Dewey, 1938/1991). That means connecting new experiences with a persons prior experience base and creating opportunities for educative new experiences. In other words, creating a social context where new experiences can lead to the moral, emotional and intellectual development of the person. From Dewey to Vygotsky (Vygotsky, 1930/1978) one strand of learning theory has focused on the individual in social context and how that context creates opportunities for learning. While there have been tremendous advancements here in our understanding of learning, it is still often thought of as primarily something that happens to the individual (even if in a social context) and something that is primarily cognitive.

Very recent work on situated learning (Lave, 1991; Lave, 1996; Lave & Wenger, 1991) activity theory (Engeström et al., 1999) and cultural theories of learning (Cole, 1996; Holland et al., 2000) have moved thinking about learning from the individual to the intersubjective experience and from the cognitive to the whole person including affective dimensions of learning. This work has led to several important implications for understanding learning. First and perhaps most importantly, learning is a social process that involves individual interest, membership in a community where others are learning and engaged in productive social practice and that knowledge is built intersubjectively and shared among members of the community. Finally the constraints on learning and knowledge production are constraints that exist within the social system, its form of organization and patterns of interaction and not within the individual. These important theoretical realizations about learning then have tremendous implication for collaborative learning and CSCL.

The emphasis on the group unit has methodological implications. The analysis of what takes place in project experiments will rely heavily upon interaction analysis (Duranti, 1998; Garfinkel, 1967; Heritage, 1984; Jordan & Henderson, 1995; Sacks, 1992) (Stahl, 2002e) and community ethnography (Renninger & Shumar, 2002). These analyses will study in quantitative and qualitative terms how small groups function to mediate the building of a larger knowledge-building community and how groups engage in sequences of different kinds of interactions to build their knowledge. Tentative theories about how this knowledge-building process takes place will be subjected to empirical study, feeding back into revised formulations of a theory of collaborative knowledge building.

While we know a great deal more about the social nature of the learning process, many of our educational institutions continue to be structured in ways that assume learning is individual and a matter of transferring information from teacher to student. That sad fact means that many of the things students learn most effectively in school are patterns of resistance and lessons from the marketplace that appeal more to a social and collaborative form of learning. While some schools have begun to implement collaborative forms of learning there are real limitations due to the political context of local schools and the difficulty of organizing resources and groups that cluster together concentrations of expertise and appeal to individual's interests. The Internet and digital libraries such as the Math Forum create an important strategic opportunity to bring a more collaborative community of practice to individuals who may be distributed geographically in different school and institutional sites. Therefore a critical next step in theoretical development is to figure out how to make online groups self-forming and self-replicating.

## 4. Pedagogy

The building of deepened understanding and increased knowledge of mathematics takes place in motivational community contexts, such as classrooms and research fields (Lave, 1991; Lave, 1996). Interactions within small groups can mediate effectively between individuals and these larger communities, providing supportive settings and engaging activities (Wenger, 1998). Small groups can build knowledge (collaborative learning) that draws upon and may extend the community knowledge while making it available to the individual participants who contribute to the group knowledge. According to theories of situated learning (Lave & Wenger, 1991), changing patterns of participation in which individuals become progressively more involved are important features of community learning; we have already seen signs of this taking place in the Math Forum virtual community in the documented example of Sonia and her son (Renninger & Shumar, 2002, p. 66 ff). This project will investigate the effects of online collaborative math learning by extending the services of the Math Forum and its growing community. It will explore the effect this has in drawing average or poorly motivated students into intellectual engagement, as well as involving students and teachers already excited about math in a larger community.

Mathematics is often thought of as the discipline of "the right answer." A small group of teachers and Math Forum (MF) staff became uncomfortable with this designation because it can interfere with efforts to help students express their mathematical thinking, learn from mistakes, experiment effectively, and pursue their mathematical interests. They asked, how can we transform the student's question "Am I right?" into "How can I develop confidence and judgment that I am on the right track when working on a problem?" and "How can I know that I am improving my mathematical problem-solving and communication skills?" They decided that engaging students in discourse about mathematics was the way to go.

Discourse can make thinking public and create an opportunity for the negotiation of meaning and agreement (Bauersfeld, 1995). At the same time, discourse provides collective support for developing one's thinking, drawing it out through the interest, questions, probing, and ideas of others (Cobb, 1995; Krummheuer, 1995; Wood, 1995; Yackel, 1995), and discourse enables students to connect their own everyday language with the specialized language of mathematics (Vygotsky, 1934/1986). Articulating what they know allows students to clarify their own understandings. Through discourse, a teacher can better grasp the mathematical needs of the class: what the students know, misconceptions they may have, and how these might have developed (Resnick, 1988). Teachers and students gain perspective on their own thoughts through the attempt to understand the thinking of others, in the process laying the foundation for a supportive learning community (Brown & Campione, 1994).

Within the mathematics education community there is strong interest in the use of discourse for teaching and learning mathematics (Atkins, 1999; NCTM, 2000; Schifter, 1996). The teacher's role is described in broad terms as facilitative, to include listening carefully to students, framing appropriate questions, and mediating competing perspectives. Students are expected to develop problem-solving skills: defining problems, formulating conjectures, and discussing the validity of solutions. Stigler and Hiebert (1998) report similar roles for teachers and students in mathematics classrooms in Japan, where mathematical discourse is an integral part of instruction.

The best way to foster domain-oriented discourse is to catalyze active small workgroups. In heterogeneous small groups, students are challenged to stretch and learn within their “zone of proximal development” “in collaboration with more capable peers” (Vygotsky, 1930/1978, p. 86). At the same time, the mentoring experience is productive for the “more capable” peer’s learning by teaching – and these roles are likely to reverse in other situations when the group members have complementary strengths.

## 5. Technology

Consider the Internet. It is a huge computational machine. It processes information reflective of the interests of millions of people. It is not simply a poorly organized repository of textual facts; it is the infrastructure of a global community. Just as no one can navigate around it easily to find the particular things of interest to them, no one can search through the world’s population to find those individuals who one might want to work with. Yet, for most people, there must be gems of information hidden out there and potential friends or colleagues who could help them to make sense of those gems. The taming of the Internet’s informational and human vastness poses the technical challenge of our time. While much research is conducted on searching and organizing the information, surprisingly little has been done on systematically bringing together and structuring groups of people on a human scale to use the Internet collaboratively.

Some organizations have explored systems for locating expertise within their staffs (Ackerman & McDonald, 1996); but the techniques for that do not transfer to the problem of finding people on the Internet with matching interests. There have been some experiments with social awareness, to display other people who are viewing the same web page at the same time (Graether & Prinz, 2001), but this hint is not enough to support group formation. A group formation project in Japan matched learning theories (Inaba et al., 2000; Supnithi et al., 1999), but not people. A prototype for group formation in Germany allowed students who knew each other to self-select groups (Wessner et al., 2002; Wessner & Pfister, 2001), but this approach does not scale to large groups who do not know each other personally. A spin-off of the German research is being expanded and developed for distance education, and the proposed Project will collaborate with that one (see section on International Collaboration).

The PI began exploring support for group formation while teaching an online HCI (Human-Computer Interaction) course for graduate students at Drexel. His students studied the issue and came up with several low-fidelity prototypes that they subjected to user testing. The PI developed an automated grouping agent, which he used to form work groups in a subsequent course. In both the student prototypes and the grouping agent, groups were formed based on specific criteria about the participants: their schedules, their interests and their skill levels. These pilot studies for the proposed project suggest the kinds of balance that should be sought in forming distributed groups. For instance, if synchronous communication is to be possible within the group – especially given different global time zones – members must have similar schedules. On the other hand, collaborative teams often work best when there is a diversity of perspectives and skills, along with a commonality of interests. Thus, a matching algorithm must optimize certain similarities and other differences. Diverse theories of collaboration stress the power of heterogeneity, of the utility of seeing things differently: cognitive dissonance (Festinger, 1957), perspectives

(Boland & Tenkasi, 1995; Goldnam-Segall, 1998; Stahl & Herrmann, 1999), interdependence (Johnson & Johnson, 1989), zone of proximal development (Vygotsky, 1930/1978), cognitive flexibility (Feltovich et al., 1996). This Project will systematically explore the hypothesis that balanced heterogeneous small groups collaborate more effectively and will develop algorithms and prototypes to implement support for this.

The pilot study of group formation was conducted with a class using two different online collaboration environments: Blackboard and BSCL. Blackboard is a commercial system to support collaboration. It is used widely in university courses, particularly in the US. Blackboard can be extended (in Java) by third party developers using the Blackboard Building Blocks SDK (see http://buildingblocks.blackboard.com/bin/bbdn_info.pl).

BSCL (Basic System for Collaborative Learning) is a system with collaboration support for classrooms that is similar to Blackboard (Stahl, 2002d). It was designed and developed by the PI and others in 2001/2002 as part of a European Union research project. BSCL is an extension (developed in Python) to BSCW (Appelt & Klöckner, 1999), a shared repository CSCW system widely used in European research and learning organizations. It is available for free to academic organizations. The PI has a license to develop it during the period of this Project (see Letter of Support in Supplementary Documentation).

The Math Forum has custom software (developed in a Perl-based environment) to support the virtual community and digital library of math resources and activities.

This Project will design, develop and evaluate software extensions to Blackboard, BSCL and Math Forum. This software will implement alternative approaches to group formation, discussion, shared representations, social awareness and knowledge management within the context of catalyzing and nurturing small groups within the Math Forum community.

## 6. Project Team

### Information Science & Technology

Drexel University has a long history of technology leadership as an Institute of Technology, including being the first university to require entering undergraduates to have a PC and the "most wired" university according to Yahoo.

Drexel University's College of Information Science and Technology is rated the #1 graduate school of library science information systems by US *News and World Report* (http://www.usnews.com/usnews/edu/grad/rankings/lib/brief/infsp3_brief.php). This interdisciplinary College offers online and campus-based undergraduate and graduate programs in computer science (e.g., HCI, databases, software engineering) and library science (including digital libraries).

The PI is an Associate Professor in the College of Information Science and Technology. He brings a multidisciplinary background to the Project, with PhD dissertations in philosophy/social theory and computer science/AI (Stahl, 1975; 1993a). He has developed a series of collaboration support systems: Hermes (Stahl, 1993b), WebNet (Stahl, 2000a), WebGuide (Stahl, 1999a; 1999b; 2001; Stahl & Herrmann, 1999), BSCL (Stahl, 2002d; 2003b), and other educational software: Teachers Curriculum Assistant (Stahl et al., 1995a; Stahl et al., 1995b) and State-the-Essence (Kintsch et al., 2000; Stahl & dePaula, 2001).

The PI specializes in CSCL research, having published on CSCL theory (Stahl, 1993b; 1998; 2000c; 2002c; 2003a; 2003c) and the use of discourse analysis as an assessment methodology (Stahl, 2002a; 2002e; 2002f; Stahl & Sanusi, 2001). He was Program Chair of CSCL 2002 and Editor of the CSCL 2002 Proceedings (Stahl, 2002b). He is Workshop Chair of CSCL 2003 and Communications Chair and founding Board member of the International Society for the Learning Sciences (ISLS) (http://www.isls.org).

### The Math Forum

The Math Forum is a program of DDrexel University. The Math Forum was founded in 1992 as the Geometry Forum at Swarthmore College, expanded to The Math Forum in 1996, and funded in its development by the National Science Foundation. It has become one of the most successful applications of the Internet to education through the development of interactive services that bridge the higher education, K12, and industry communities. These services form the basis for a knowledge building environment that generates high quality mathematical content, supports student learning, integrates the benefits of technology with education, and is used for teacher professional development and pre-service teacher education. The Math Forum now comprises over 1.2 million pages of content, has over 2 million visits a month, receives up to 9,000 queries a month at its Ask Dr. Math expert service, and mentored over 27,000 students during the 2000-2001 school year through its Problem of the Week services. Among its current projects are two NSF grants, one focused on the use of online student mentoring programs in pre-service teacher education courses, and the other on the development of MathTools, a digital library for software in mathematics education, arithmetic-calculus.

### Education & Ethnography

Drexel University also has a School of Education and a Department of Culture & Communication, both of which are represented in this Project. Prof. Craig Bach of the School of Education explores the use of technology in education, having developed several hypermedia presentations of topics in mathematics and philosophy. Prof. Wesley Shumar is a cultural anthropologist in the Department of Culture & Communication who specializes in educational anthropology and has conducted ethnographic studies of the Math Forum for many years.

### National and International Collaborators

A unique feature of this Project is the involvement of leading national and international researchers. They bring expertise from a variety of relevant specialties and perspectives. Their participation will provide a natural means for sharing practical knowledge from Europe and the US as well as for disseminating the results of this Project across the nation and globe. To ensure a strong cadre of collaborators, the following researchers have already expressed strong interest in participating in the Project; others can join in the future:

**Americans**: Geri Gay (Cornell), Ricki Goldman-Segall (NJIT), Cindy Hmelo-Silver (Rutgers), Christopher Hoadley (Penn State), Timothy Koschmann (Southern Illinois U), Bonnie Nardi (Agilent), Leysia Palen (Colorado), Linda Puliam (California State U.), Mark Schlager (SRI).

**International**: Wolfgang Appelt (Fraunhofer-FIT, Germany), Hugo Fuks (Rio, Brazil), Joerg Haake (Distance U, Germany), Kai Hakkarainen (Helsinki, Finland), Thomas Herrmann (Dortmund, Germany), Jim Hewitt (Toronto, Canada), Victor Kaptelinin (Umea, Sweden), Anders Morch (Oslo, Norway), Wolfgang Prinz (Aachen, Germany), Barbara Wasson (Bergen, Norway), Volker Wulf (Siegen, Germany).

These individuals are established leaders in the HCI, CSCW and CSCL research communities, having made important contributions in theory, system design and assessment methodology. They all recognize the importance of collaboration, both in theory and in practice. See the Biographical Sketches section for more information.

## 7. Prior Work with NSF and European Commission Funding

### 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 (http://mathforum.org) of over 925,035 learning resources and it receives over 650,000 visitors a month (making 2 million visits), 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 (http://mathmetadata.org/).

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 (Renninger & Shumar, 2002a; 2002b; Shumar & Renninger, 2002); Problems of the Week (Renninger et al., 2000; Renninger & Shumar, 1998); geometry interactions (Renninger et al., 1989).

### JOMA Applet Project

*DLI-2 Award Number 9980185*

Its goals were to 1) search the Web and 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) 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.

### MathDL

*NSDL Award Number 0085861*

MathDL is an undergraduate-level digital library, a joint project between the MAA and the Math Forum, which is developing the technical infrastructure. 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.

### ESCOT (Educational Software Components of Tomorrow)

*REC Award Number 9804930*

was a testbed 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.

### 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.

### Organizational Memory and Organizational Learning (CSS)

*"Conceptual Frameworks and Computational Support for Organizational Memories and Organizational Learning (OMOL)," PIs: Gerhard Fischer, Gerry Stahl, Jonathan Ostwald, September 1997 – August 2000, $725,000, from NSF CSS Program #IRR-9711951.*

This grant was instrumental in the PI's turn from earlier work on organizational memory to support for collaborative learning. The OMOL project started from a model of computer support for organizations as domain-oriented design environments in which both domain knowledge and local knowledge are stored in the form of artifact designs and associated design rationale (Fischer et al., 1993). This CSCW model evolved into one of Collaborative Information Environments (CIEs), that emphasized the interactive, asynchronous, persistent discussion of concepts and issues within an organization (Stahl, 1998; 2000a). Gradually, interest in organizational learning aspects led to involvement in CSCL and the model of collaborative knowledge-building environments (Stahl, 2001). A number of software prototypes were developed to explore the use of the Web as a communication and collaboration medium. Of these, the most important for the proposed work was WebGuide a prototype threaded discussion system that provided multiple perspectives on the discussion, comparison of perspectives and control over rearrangement of notes (Stahl & dePaula, 1998; Stahl et al., 1998). Deployment of WebGuide in classrooms raised serious issues of adoption and concerns of socio-technical and social informatics (Kling, 1999) issues: motivation, media competition, critical mass, social practices, seeding, management, re-seeding, convergence of ideas, peer-to-peer collaboration, deployment strategies.

### WebGuide and Environmental Perspectives (NOAA)

*"Collaborative Web-Based Tools for Learning to Integrate Scientific Results into Social Policy," PIs: Ray Habermann, Gerry Stahl, November 1998 – July 1999, $89,338, NSF, #EAR-9870934.*

This grant funded the initial implementation of WebGuide as an integrated Java applet supporting personal and group perspectives. It was a joint effort between the PI, a middle school teacher, and a research group at the NOAA labs in Boulder. The teacher taught an environmental science class in which he wanted to spend the year having his students interview various adults and construct a set of contrasting perspectives (conservationist, regulatory, business, community) on a particular local environmental issue that the students had previously been involved in. WebGuide was used by the students to collect notes on their interviews and to formulate personal and team perspectives on the issue. Results of this software trial were analyzed and presented at conferences (Stahl, 1999a; 1999b; 1999c; Stahl & Herrmann, 1999).

### Innovative Technology for Collaborative Learning (European Commission)

*"Innovative Technology for Collaborative Learning," Fraunhofer-FIT and researchers in Finland, Spain, Netherlands, Italy and Greece. May 2001 – May 2003. European Commission Project IST-2000-26249.*

This grant supported software design and development of BSCL by researchers in Finland, Germany and Spain. The software was implemented as extensions of BSCW, a mature CSCW product used by 200,000 unique users since 1996 (Appelt, 1999). The PI went to work with the BSCW team at Fraunhofer-FIT near Bonn, Germany, for the first year of the project. He prototyped the BSCL innovations and published descriptions of them (Stahl, 2002d; Stahl, 2003b). During its second year, the project is assessing the use of the new software in schools in Finland, Netherlands, Italy and Greece.

## 8. International Collaborations

The proposed NSF Project builds on the work of the European ITCOLE Project and its BSCL software. The PI was the primary designer and prototyper of the BSCL software when he worked at Fraunhofer-FIT in Germany. The Project with the Math Forum will involve close collaboration with the BSCW/BSCL team at FIT and has their full support. FIT will continue to support the BSCL code, making it available for free to educational institutions throughout the world. They will also provide training to Project staff who will be modifying the BSCL code. FIT has granted a five year developers license to the PI to work on extending BSCL as part of this Project. Both Wolfgang Appelt, the BSCW/BSCL team manager and Wolfgang Prinz, the director of the CSCW department at FIT personally support the proposed Project and its collaboration with FIT (see Supplementary Documentation).

The idea of automated support for group formation for workgroups in online learning is a research topic at the Distance University of Germany (Fern-Uni, Hagen). Joerg Haake, who has begun research on this topic (Haake et al., 2003; Wessner et al., 2002) will be a close collaborator with this Project.

In general, a number of leading international HCI, CSCW and CSCL researchers have already agreed to collaborate on this Project, participating in the workgroups that will conduct much of the project planning, experimental designing, software design and assessment. Others will be added as needed. The names, affiliations and research interests of these international collaborators are listed in the attached Biographical Sketches section.

## 9. Project Assumptions, Hypotheses & Methods

The global design of the Project is diagrammed in Figure 1. The core question is how best to balance group formation and how best to support the collaborative learning of the formed groups. The global hypothesis is that carefully balanced groups and properly supported or coached groups (the upper, right quadrant) will learn better and produce higher quality results. This hypothesis is tested by comparing groups in which differences among the members have been balanced in accordance with various algorithms with randomly assigned or self-selected groups. Then, an assortment of software tools and structures will be used to support the collaboration processes of the groups. The results of groups with these supports will be compared with the results of groups without these special supports. Thus, the Project will not only demonstrate that groups in the upper right quadrant learn better (assuming the global hypothesis is confirmed), but it will also be able to distinguish the effects of the structure of the catalyzed groups from the effects of their nurturing.

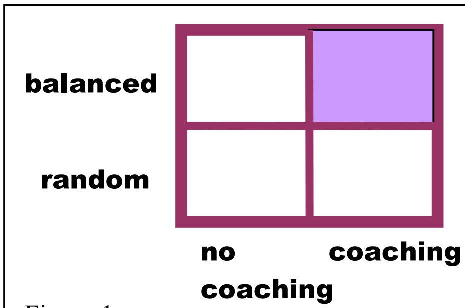

Figure 1.

To test the global hypothesis, a number of assumptions and secondary hypotheses are made:

Assumption 1: Collaborative learning is good. While we will investigate the processes of collaborative learning and discover much about its power, its difficulties and its limitations, this Project will not focus on comparing it with individual learning.

Assumption 2: Small groups are useful for building communities. The Project looks at virtual communities like the Math Forum as being built out of the interactions of individual members as they participate in small groups; it will observe the forms of leadership, changing roles, group continuities and community structures that emerge and evolve as groups are catalyzed or as they spontaneously form.

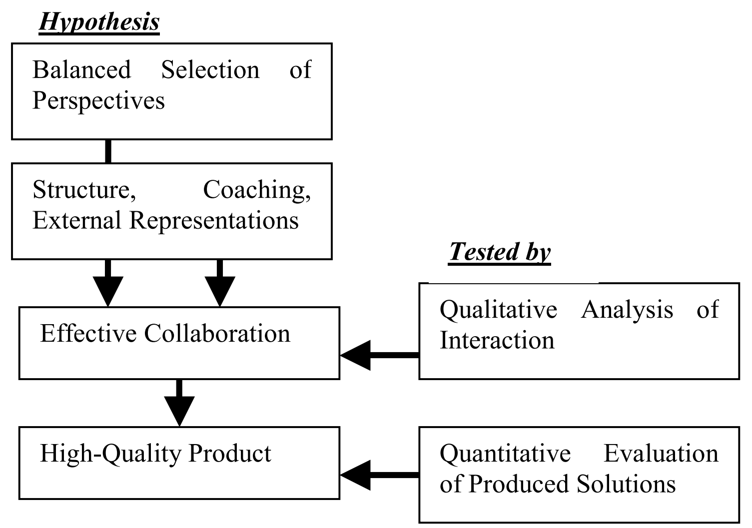

Figure 2

Assumption 3: It is useful and sufficient to focus on the group as the unit of analysis. While it is necessary to analyze the contributions of individuals to a group's learning, it is possible to interpret the meaning of group discourse without making assumptions about or investigating the psychological states or personal interpretations of the individual members. The Project will only use instruments like individual interviews and post-tests in focused and limited ways.

Assumption 4: The success of collaborative learning at the group level can be measured by quantitative evaluation of the group products (such as solutions to math problems and the rationale for the solution). In addition, the Project will take a qualitative look at group process, but this will not provide the primary judgment of a group's success.

Assumption 5: The intertwining of differing perspectives is productive of group learning.

Assumption 6: Collaboration is a complex process and people must learn how to interact productively.

Hypothesis 1: Catalyzing carefully balanced heterogeneous groups will create groups that learn better than randomly assigned groups.

Hypothesis 2: Providing tools that help groups to structure their interactions, that support specific phases of their collaborations and that coach their group process will create groups that learn better than they would have without those tools.

Method 1: The Project will assess the effect of balanced formation and support for collaboration primarily by quantitative evaluation of the group's produced solutions to problems (see Figure 2).

Method 2: Secondarily, the Project will analyze the group interaction to assess the quality of the collaborative process.

## 10. Plan of Work

The five year Project period is planned to be January 1, 2004 – December 31, 2008. Roughly, work during these years will be focused as follows:

- Year I (2004) pilot studies;
- Year II (2005) controlled experiments;
- Year III (2006) prototype evaluations;
- Year IV (2007) field studies;
- Year V (2008) scaling, refinement, assessment and dissemination.

This Project is based on a belief in the power of collaborative knowledge building. Therefore, the Project will be a highly collaborative effort – and the success of that effort will itself be an object of study in the Project. Accordingly, the work will be conducted through the organization of three sets of workgroups: student workgroups, curricular workgroups and infrastructure workgroups. Project staff will be responsible for organizing these workgroups and coordinating the activities and results of the Project.

### Project Staff

Project staff is based at Drexel University and works out of the Math Forum offices. Their primary activities will be related to supporting the catalyzing and nurturing of the student, curricular and infrastructure workgroups. Staff will be responsible for ensuring that these groups get started and function effectively to carry out their roles in the Project. It is acknowledged that most of the workgroup members are volunteers with significant limits on their time and that staff will have to support them to allow them to focus their effort effectively on making their most important contributions. Staff will work closely with these groups (including as members of the curricular and infrastructure workgroups) and will carry out the daily activities needed to implement the plans of these groups, such as drafting detailed proposals for the groups to review, transcribing videotapes, prototyping / implementing / releasing newly designed software, conducting statistical analyses of data, collecting / documenting / preserving Project data and materials. They will make all Project data and materials available online to the infrastructure workgroups and will ensure that these are preserved for future purposes. They will ensure that all logs and transcripts are distributed and preserved in a manner that protects privacy of students and guarantees anonymity, in keeping with a human rights protection plan approved by Drexel's Institutional Review Board. Project staff will be responsible for the successful functioning of the Project and for the production of required reports and other documentation.

### Student Workgroups

Student workgroups are primarily organized online, although some Year I activities will take place face-to-face in local school classrooms. Student workgroups will increasingly be supported by online tools created as part of the project. They will be one of the sets of workgroups studied in the Project.

Year I: Pilot studies will explore collaborative learning using Math Forum problems in local middle- or high-school contexts, in face-to-face situations or with commercial mediation systems like instant messaging. We will look at some existing math classroom collaborative learning situations and learn from these about selection, process, and problem design. These could include some classrooms where they are doing the Problem of the Week. Generally, groups of 3 to 6 students will be selected by hand, with teacher input. Principles of group selection and group process from the classroom practice, from the research literature and from project hypotheses will be tested in this context. This is a highly explorative, qualitative phase of the project to build a focused experience base of small student groups working on collaborative Problems of the Month. Selected face-to-face interactions will be videotaped, digitized and transcribed. Transcripts and computer logs will be logged and reviewed to identify key interactions, which will be subjected to detailed discourse analysis and complementary forms of micro-ethnographic analysis.

Year II: Controlled experiments of groups working on Math Forum problems will compare groups with different selection criteria: self-selection, teacher selection, homogeneous matching, heterogeneous balancing, knowledge complementing, random. Early computer prototypes of software for the selection process will be tested. These experiments will generate quantitative and qualitative data related to evaluation of the group's problem solution. Experiments will also be conducted to explore different kinds of math problems: longer time periods, more open-ended, more discussion-oriented, supportive of modeling.

Year III: Prototype evaluations will start to introduce tools for group selection and group scaffolding designed as part of the Project and based on the results of the previous two years' results. Experiments this year will focus on alternative forms of scaffolding, including automated group process guidance, human facilitation and tools to support specific group processes (such as brainstorming, discourse, knowledge management, math representations, negotiation, textual references).

Year IV: Field studies will be done by enhancing the Math Forum environment with tools based on previous results. These will be focused experiments to monitor the rate of participation, the need for outreach and the extent to which pilot mechanisms scale. This will permit students from the broader Math Forum virtual community to be invited into workgroups. The interaction of selection criteria and forms of scaffolding will be studied (e.g., whether certain tools are more helpful for certain types of groups).

Year V: Experiments in the final year are reserved for unanticipated follow-up studies whose need is indicated by preliminary assessment of the Project results. This is a time to scale-up use of the group formation and scaffolding tools to become a normal part of the Math Forum. Observations will be made of the impact of collaborative student workgroups on the growth and dynamics of the virtual community, on the nature of the mathematical problem-solving and learning taking place and on the interest of participants in mathematics.

### Curricular Workgroups

Curricular workgroups are primarily organized online, although some activities will take place face-to-face at the Math Forum or at special workshops held annually for mentors, teachers and student teachers in the curricular workgroups. Curricular workgroups will increasingly be supported by online tools created as part of the project. They will be one of the sets of workgroups studied in the Project.

Year I: Pilot studies will explore collaborative design of new Math Forum problems, in face-to-face situations or with commercial mediation systems like instant messaging. Problems will be designed for use by collaborative workgroups of students. Groups of 3 to 6 participants will be selected by hand, from the pool of teachers, student teachers and mentors who assist in defining new math problems. Principles of group selection and group process from the research literature and from project hypotheses will be tested in this context. Sample F2F interactions will be videotaped, digitized and transcribed. Transcripts and computer logs will be logged and reviewed to identify key interactions, which will be subjected to detailed discourse analysis and complementary forms of micro-ethnographic analysis. This is a highly explorative, qualitative phase of the project to build a focused experience base of small adult groups devising Problems of the Week.

Year II: Controlled experiments of groups designing Math Forum problems will compare groups with different selection criteria: self-selection, staff selection, homogeneous matching, heterogeneous balancing, knowledge complementing, random. These experiments will generate quantitative data related to evaluation of the group's problem generating ability. In addition to designing new problems suitable for collaborative student workgroups, the curricular workgroups will design ways of incorporating such collaborative problem-solving in school classrooms, possibly mixing workgroups across schools or even across countries (taking into account issues of language and time zones, for instance).

Year III: Prototype evaluations will start to introduce tools for group selection and group scaffolding designed as part of the Project and based on the results of the previous two years' results. Experiments this year will focus on alternative forms of scaffolding, including automated group process guidance, human mentoring, tools to support specific group processes (brainstorming, discourse, knowledge management, math representations, negotiation, textual references). The tools for adults searching the problem database and designing new problems may be different from the tools for students solving problems.

Year IV: Field studies will be done by enhancing the Math Forum environment with tools based on previous results. This will permit teachers and mentors from the broader Math Forum virtual community to be invited into these workgroups as they demonstrate interest and background for this work. The interaction of selection criteria and forms of scaffolding will be studied (e.g., whether certain tools are more helpful for certain types of groups).

Year V: Experiments in the final year are reserved for unanticipated follow-up studies whose need is indicated by preliminary assessment of the Project results. This is a time to scale-up use of the group formation and scaffolding tools to become a normal part of the Math Forum. Observations will be made of the impact of curricular mentor workgroups on the growth and dynamics of the virtual community, such as how it enables adults to move into more central forms of community participation.

### Infrastructure Workgroups

Infrastructure workgroups consist of Project staff and collaborators from the international CSCL community. They are primarily organized online, although some activities will take place face-to-face at intensive week-long annual workshops. Infrastructure workgroups will increasingly be supported by online tools created as part of the project. They will be one of the sets of workgroups studied in the Project. The infrastructure workgroups will help to clarify applicable theory, point to existing relevant literature, define appropriate pedagogy, develop experimental methodology, specify technology requirements, evaluate software designs and provide on-going formative assessment of Project progress. The Math Forum has participated in projects with developers in the past, holding intensive workshops and using Web-based tools for collaborating on project development, taxonomies, working group support, etc. – this Project will build on such experience.

Year I: Four infrastructure workgroups will be formed, each including European researchers, American researchers and Project staff. Each group will have a multidisciplinary mix of skills: technical, psychological and pedagogical. They will design and monitor the pilot studies of the student and curricular workgroups and will participate in the analysis of the results.

Year II: The infrastructure workgroups will design and monitor the controlled experiments of the student and curricular workgroups and will participate in the analysis of the results.

Year III: The infrastructure workgroups will design and monitor the prototype evaluations of the student and curricular workgroups and will participate in the analysis of the results. They will also start to use some of the new tools for their own collaborations.

Year IV: The infrastructure workgroups will design and monitor the field studies of the student and curricular workgroups and will participate in the analysis of the results, including studying the interaction of selection criteria and forms of scaffolding.

Year V: The infrastructure workgroup members will disseminate the results of this Project at conferences, other projects and publications, both in the US and abroad. They will analyze the effect of active workgroups on the growth and dynamics of the larger virtual community, such as how it results in community knowledge and in changing patterns of participation.

## 11. Project Assessment

The evaluation for the Project is designed to provide specific data about the quality of interactions in the different workgroups. as well as assess the overall success of the project. Data collected will largely be descriptive ethnographic data, which is appropriate to the needs of the Project. Our goal will be to provide a detailed description of the interactions within each of the kinds of workgroups and to interview participants in the workgroups so that we have their feelings about how well the group worked. These descriptions will allow Project staff to assess which workgroups are doing well and which ones are less successful. Drawing on prior Math Forum work with the ESCOT project, workgroups will be evaluated in terms of their ability to communicate, develop a sense of shared worldview and create a feeling of group belonging – all of which contribute to successful work practices (Shumar, 2002; Lave & Wenger, 1991; Wenger, 1998). Analysis of the experiments with the workgroups will also contribute to the overall evaluation of the project and the success of it’s implementation. Specific details of the research are discussed below.

In year I the analysis of student workgroups will consist of two categories: face-to-face groups and virtual groups. We will observe 4 sites in schools where collaborative group work is ongoing. These may be groups using the Math Forum environment and they may be doing other projects. As mentioned above, in year I the face-to face sites will involve extensive observation over the period of the collaborative problem solving. This may involve regular classroom participation for a week or two. Interactions will be videotaped and participant observation data will be collected. In addition to the 4 face-to face sites, 12 virtual workgroup sites will be established. These will be random virtual groups of students who have volunteered to work collaboratively on the math problems. Data from these groups will be collected on synchronous and asynchronous forms of interaction (chat transcripts, discussion lists, emails, and interviews with participants). Preliminary analysis of this student data will assess the patterns of interaction and begin to create a typology of successful group dynamics as well as get participants’ sense of the quality of the group interaction. Drawing on earlier work on mathematical thinking at the Math Forum, interactions will also be assessed for the quality of the work that went into the problem-solving in the group (Renninger, et al., 2000).

The year I curricular workgroup evaluation will be based on the analysis of four workgroups over the course of the year. Interactions in these workgroups will be tracked on synchronous and asynchronous forms of interactions (chat transcripts, discussion lists, email, and interviews). Face-to-face interactions of the workgroups will be videotaped and observed directly. Analysis of group interaction and discourse will center around the emerging patters of leadership, creation of a sense of group belonging, and the ability to communicate across differences of group, culture, need, etc.

Finally 4 infrastructure workgroups will be evaluated by collecting virtual chat interactions, discussion lists and interviews with members of the group. Analysis of group interaction will follow the same pattern as the curricular workgroups.

In years II through V, evaluation of the student workgroups will follow a similar format to the evaluation of the virtual groups in year I. 10-12 groups will be evaluated. Data collected will come from synchronous and asynchronous forms of interaction plus teacher interviews on the impact of the workgroup on the students' classroom interactions. Problem solving will be analyzed in terms of the group's process of mathematical thinking and interaction. The qualitative data will also be analyzed looking at the impact of group heterogeneity on individual learning and the effect of group composition on collaborative learning moments. The better performing groups of each year will be compared with the method of group selection.

In years II through V curricular and infrastructure workgroups evaluation will follow the pattern set up in year I. Four curricular and four infrastructure groups will be studied each year. Data will be collected through synchronous and asynchronous communication and interviews with group members. Data analysis will follow the pattern established in year I and will be done to identify effective workgroups as well as groups that enhance the development of individual members of the group. Effective workgroups will then be compared with models of selection for the group.

## 12. Dissemination of Results

Dissemination of Project results, both in the US and in Europe, is built into the Project design. Dissemination to the international research community, to practicing educators and to the public generally will take place primarily through the following mechanisms:

- Workshops at CSCL conferences. The Project workshops that bring together international and American researchers in the infrastructure workgroups and teachers in the curricular workgroups will sometimes be coordinated with international conferences on education such as CSCL, ICSL, AERA and EARLI. Most of the researchers involved in this Project regularly attend these conferences and present at them. These conferences will be primary sites for the presentation of results from this Project.
- Involvement of international researchers. Approximately two dozen researchers will be intimately involved in this Project, primarily through the infrastructure workgroups. In many cases, their students will also be involved.
- Involvement of teachers and student teachers. Perhaps two dozen teachers and student teachers will be intimately involved in this Project, primarily through the curricular workgroups. As the results of this Project become part of Math Forum's regular services, increasing numbers of teachers and student teachers will participate in spontaneously formed curricular workgroups.
- The Math Forum virtual community. This is a rapidly growing community that already numbers over a million distinct individuals. They will learn about the results of this Project as collaborative problems become a regular feature of the Math Forum and as community participants are automatically invited to join small groups for collaborative learning of mathematics.

## 13. Anticipated Results & Impact

**Intellectual Merit**: This Project explores a primary open challenge of the Internet – with detailed and rigorous methods, under controlled and real-world global conditions: how to foster effective collaborative online learning. It joins the multidisciplinary expertise of the international CSCL community with the practical success of the Math Forum to study how to mediate the growth of a large virtual learning community, and to design, develop and assess tools for the automated support of small workgroups acquiring, managing and negotiating knowledge.

**Innovation in IT:** An unfulfilled promise of the Internet is to bring together systematically people who do not live close by, but who could benefit from interacting within knowledge-rich contexts. This Project addresses core issues of computer support for collaborative learning (CSCL): how best to form and structure intimate learning workgroups within global knowledge-building communities and how to effectively scaffold their interactions.

**Integration of Research & Education**: The Math Forum is a major practical success of prior NSF research, forming a virtual community of about a million students, teachers and mathematicians. This Project will systematically initiate and support efforts to form small collaborations within the large body of users who now interact as individuals with the site. This fundamental research into innovative support for small group collaborative online learning will take place within a vibrant and realistic large-scale context and will impact all levels: student motivation and learning, teacher development, and community evolution – generating a new model of global virtual learning communities, incorporating the power and motivation of small-group collaboration.

**Broader Impacts**: The Math Forum model, with automated formation of small groups and support for interactions developing deep understanding of mathematics, will be suggestive for virtual learning communities in other domains, taking advantage of other digital libraries. This model provides opportunities for students and teachers excluded from collaborative learning due to geographic isolation, disadvantaged schools, physical disability, discrimination and other physical or social factors. The model stimulates both student motivation and teacher development, transforming interest in mathematics from a social stigma into a bridge to global friendships.

**Integrating Diversity**: A central Project hypothesis is that groups integrating specific kinds of diversity learn better.

**International Collaboration**: The Project builds on the PI's prior work on an EU grant. Core aspects of the Project – including technology design, pedagogy and assessment – will be conducted by workgroups of American and European leaders of the CSCL community in collaboration with Project staff. Annual week-long intensive workshops will bring these collaborators together with each other and with teachers and Project staff.

## 14. Management Plan

The PI, Stahl, will have primary responsibility for all aspects of the Project, especially the research direction. Weimar and Stahl will share Project fiscal management, with accounting maintained by the Math Forum and Drexel University. Weimar and Stahl will share Project staff management, recognizing that most staff are long-time employees of the Math Forum contributing part-time to the Project and that three staff are graduate research assistants hired through the College of Information Science & Technology or the Department of Anthropology.

The Project Management Team consists of the four co-PIs and will meet twice a month:

- G. Stahl, Information Science
- S. Weimar, Math Forum
- C. Bach, Education
- W. Shumar, Anthropology

The Project Staff consists of the four PIs, four Math Forum curricular staff, three Math Forum technical staff and three graduate research assistants:

- G. Stahl, Information Science – Infrastructure Workgroup Coordinator
- S. Weimar, Math Forum – Student Workgroup Coordinator
- C. Bach, Education – Curricular Workgroup Coordinator
- W. Shumar, Anthropology – Evaluation Coordinator
- I. Underwood, Math Forum – MF Ask Dr. Math
- A. Fetter, Math Forum – MF Problem of the Week
- K. Lasher, Math Forum – MF Problem of the Week
- S. Alejandre, Math Forum – MF Problem of the Week
- L. Smith, Math Forum – MF IT director
- D. Tristano, Math Forum – MF software developer
- J. Zhu, Math Forum – MF system administrator
- GRA, Information Science & Technology – Blackboard developer
- GRA, Information Science & Technology – BSCL developer
- GRA, Anthropology – ethnographer

The Project Staff will hold monthly meetings at the Math Forum offices. These meetings will plan detailed Project milestones and activities; review progress made according to the milestones; prepare for up-coming activities; review and revise the Project plan; and make other decisions about the Project as needed. Minutes of these meetings will be posted on the Project website with other Project resources for review by the infrastructure workgroups.

Project management will be conducted following a collaborative model, in keeping with the philosophy of the Project. Project activities will involve the collaborative workgroups, with Project staff providing staff support and taking responsibility to ensure tasks are accomplished. Each set of groups will be coordinated by a co-PI: Weimar (student workgroups), Bach (curricular workgroups), Stahl (infrastructure workgroups). The Project takes an assessment-heavy approach to investigating the requirements for and effectiveness of technology; Shumar will coordinate the experimental design, ethnographic investigation, and formative and summative assessment of the Project. Stahl is responsible for software design and development; Smith for integration of software into the Math Forum site; Weimar for involvement of students and teachers, as well as integration of Project activities with other Math Forum activities; and Bach for pedagogical aspects of the Project.

Development of collaborative Problems of the Month and other curricular materials will be done through the curricular workgroups, consisting primarily of teachers and student teachers. The infrastructure workgroups – including national and international researchers as well as Project staff and interested members of the curricular workgroups – will assist in the design and evaluation of Project experiments and of software for use in the experiments; they will monitor and guide the progress of the Project. All workgroups will be encouraged to be self-reflective and to become increasingly involved in the Project.

The Math Forum Problem of the Week staff will participate in planning, design and facilitation of the student and curricular workgroups. Math Forum staff will help with logistics, using their existing systems and networks of contacts. They will also help with hosting the annual week-long intensive workshops.

Shumar will coordinate all data collection, working with an RA, and will focus the workgroups as needed for formative evaluation tasks. Stahl is responsible for Project reports, including annual reports to NSF, culling from workgroup summaries. Stahl, Bach and Shumar will prepare papers for conferences.