Section C. Project Description

> However well they may have been prepared to teach, and whatever knowledge they may have gained in Summer Institutes, all teachers need continuing, collegial contact, peer reinforcement and input from experts to sharpen their skills and deepen their subject knowledge.
>
> — *National Commission on Mathematics and Science Teaching for the 21st Century*

The Promise of Online Education Communities of Practice

Researchers (Lieberman, 1996; Darling-Hammond & Ball, 1997; Loucks-Horsley, Hewson, Love, & Stiles, 1998; Thomas, Wineburg, Grossman, Myhre, & Woolworth, 1998; Corcoran, Shields, & Zucker, 1998), practitioners (Rényi, 1996; CEO Forum, 1999; AACTE, 2000), and policy-makers (PCAST, 1997; National Commission on Mathematics and Science Teaching, 2000) are converging on the view that communities of practice (CoPs) in the teaching profession can be powerful catalysts for improving teachers' practice and facilitating systemic reform. Advocates have been attracted to the CoP concept to help overcome limitations of traditional teacher professional development (TPD), which is heavily skewed toward pockets of formal, highly structured activities outside the context of teachers' actual work (Darling-Hammond & Ball, 1997). Even exemplary TPD efforts (Ruskus & Luczak, 1995) have found it difficult to maintain support for teachers after an institute or workshop, to encourage sustained discourse among teachers, and to scale up through traditional dissemination mechanisms (Corcoran et al., 1998).

The intuitive appeal of the CoP concept is supported by research on CoPs in the workplace (Lave & Wenger, 1991; Orr, 1996; Wenger, 1998; Cothrel & Williams, 1999; Brown & Duguid, 2000) and in education (Lieberman, 1996; Lieberman & Grolnick, 1999; Laferrière, 2000; Lamon, Reeve, & Caswell, 1999; Barab & Duffy, 2000). Moreover, education technology research suggests that SMET TPD and education reform programs can use Internet technology to help education professionals overcome isolation and lower barriers to participation in TPD activities (Ruopp, Gal, Drayton, & Pfister, 1993; Hawkins, 1996; PCAST, 1997; Pea, 1999; National Commission on Mathematics and Science Teaching, 2000). Together, reform-based SMET TPD strategies (e.g., Loucks-Horsley et al., 1998) and emerging Internet technologies promise to enable all education professionals to satisfy their right-in-time professional development needs (Putnam & Borko, 2000); enable SMET preservice and novice educators to learn through participation in the activities of the practitioner and scientific communities (Wattenberg, 1998); enable journeymen practitioners to become valued resources and community leaders; and enable researchers and practitioners to engage in effective collaborations.

Although the online CoP vision is compelling and theoretically sound, the reality of online teacher communities has been less promising. The reason, we believe, is that research into the marriage of TPD pedagogy and online technology is missing a necessary third component: the infrastructure for online CoPs (as distinct from particular online TPD strategies). We argue that the CoP infrastructure—not the specific pedagogical approach or communication technologies used—contains the mechanisms (social and technological) that lower barriers to access, facilitate participation and professional discourse practices, and establish sustainable, scalable supports for teachers and TPD providers. To realize the promise of online teacher communities, we must conduct the research needed to better understand the social and organizational structures of online CoPs as an integral component of the teaching profession, not simply as an appendage of particular TPD strategies.

To advance this research agenda, we must also break free of the constraints that conventional "distance learning" tools place on the research. We must build technological infrastructures that reflect and augment the social and organizational structures of a CoP, not those of a classroom. In the proposed 16-month pilot project, a multidisciplinary team will apply what we and others are learning about the structures and affordances of online education CoPs to design and prototype a new technical infrastructure for online CoPs that will support research (our own and that of other research projects) over the next several years. The prototype is also intended to serve as a foundation for subsequent development efforts by the partners in this project and others. We will document the design process on a public Web site and solicit feedback and commentary from the research and practitioner communities to widely disseminate knowledge of online CoP design issues and arrive at design guidelines that will inform technology research and development aimed at supporting online education communities.

The Need for Research on Online Education Communities of Practice

Despite the broad agreement about the *promise* of online CoPs in the teaching profession, most attempts to supplement TPD experiences through online teacher communities have proven disappointing to both the teachers involved and the TPD project staff (Donnelly, Dove, Tiffany, Adelman, & Zucker, 2000). Very few online TPD projects have resulted in online communities that are sustainable enough to support teachers as they engage in the process of classroom reform or scalable enough to support all teachers as they enter the profession and grow professionally toward mastery (Corcoran et al., 1998). We believe that a major reason for the lack of success has been a lack of research with online teacher CoPs as its *primary* focus (Schlager, Fusco, & Schank, in press).

Typically, SMET TPD research projects (e.g., Ruopp et al., 1993; Marx, Blumenfeld, Krajcik, & Soloway, 1998; Wiske, Sweeny, & Moore, 1998; Koufman-Frederick, Lillie, Pattison-Gordon, Watt, & Carter, 1999) address the concept of teacher community primarily as it relates to a selected group teachers engaged in a prescribed, highly structured set of TPD interventions and/or curriculum objectives. Common practice is to supplement face-to-face activities with e-mail or Web-based communication tools, such as newsgroups, discussion boards, group Web pages, instant messaging, and chat rooms. Teachers are encouraged to engage in online discussions, *publish* their projects and lesson plans, and participate in distributed online projects (sometimes with their students). Some projects deliver entire TPD courses via Web-based (e.g., WebCT, Blackboard), server-based (e.g., FirstClass, Lotus Domino), and proprietary content (e.g., Classroom Connect, Lightspan Partnership) systems. The focus is the course or institute, the participants *are* the community, and technology is employed to support a particular pedagogy. In such projects, the participants frequently do not get beyond the early stages of community development, or what Grossman, Wineburg, and Woolworth (2000) call "pseudo-community." The findings can reveal little about how authentic online CoPs take root, mature, and function, the structures that support them, or the effects CoPs have on their members (Blanton, Mooreman, & Trathen, 1998).

CoPs are not groups of people who happen to be taking a particular class, subscribing to the same discussion board or e-mail list, or recruited into a project by researchers. Nor are CoPs inherently beneficial, as is assumed in most TPD research; they can undermine as well as facilitate innovation, subvert as well as support a system. A CoP is a self-reproducing socio-organizational system in which newcomers develop mastery of the community's knowledge and practices through encounters with people, tools, tasks, and social norms in authentic work contexts (Lave & Wenger, 1991; Wenger, 1998). Few SMET education research projects can be said to reflect this characterization of community (notable exceptions are the Math Forum and the Bay Area Writing Project, which has grown into the National Writing Project). To understand the roles that CoPs can play in TPD, we must cultivate and study CoPs, not approximations that emulate one or two characteristics of a CoP (Barab & Duffy, 2000).

We illustrate the urgent need for a CoP-focused research agenda with an example of the type of recommendation that is becoming common in education technology policy documents. The National Commission on Mathematics and Science Teaching report cited above calls for the development of a national network of teacher *Inquiry Groups*. The report suggests that "such groups can readily take advantage of local resources (e.g., businesses, museums, laboratories), other Inquiry Groups from neighboring districts, and faculty from nearby two- and four-year higher education institutions. Inquiry Groups could also be networked electronically, via distance learning technology, for wider sharing of information, instruction, and resources." The recommendation, which has several CoP characteristics, sounds straightforward; yet many challenging design questions are hidden in the details for which current research has few answers:

What is an Inquiry Group, and how do such groups develop the discourse practices, shared values, and relationships needed to engage in meaningful discourse? Ball and Cohen (1999) suggest that "In order to inquire, especially into one's own practice, professionals must cultivate dispositions as well as technical and intellectual knowledge and skills" (p. 27). They argue that teachers must "unlearn the politeness norm that dominates most current teacher discourses" (p. 27). Grossman, Wineburg and their colleagues (Thomas et al., 1998; Grossman et al., 2000) found that it took a year of a research team's leadership to get a group of teachers at one school, face to face, to develop such dispositions and function as a learning community. One conclusion that might be drawn from these studies is that new TPD interventions are needed to train

teachers how to engage in Inquiry Groups; in essence teachers need pre-TPD in discourse skills in order to participate effectively in SMET TPD. Another view is that teachers can learn discourse skills in the context of SMET TPD programs. We believe that professional discourse skills can be learned more rapidly and effectively though self-motivated participation in professional discourse within an online CoP rather than in a weekend workshop or SMET TPD program.

How exactly can Inquiry Groups take advantage of local resources (e.g., businesses, museums, laboratories), other Inquiry Groups from neighboring districts, and faculty from nearby higher education institutions? Where do teachers who do not have local resources turn for help? Universities, museums, and scientific organizations are struggling to figure out cost- and time-effective ways to support teachers online (see New England Aquarium letter of support). Few have found sustainable ways to support local teachers.

How exactly will a national electronic network of Inquiry Groups form, share support, and construct new knowledge? Who are the leaders and organizers? How is knowledge built, organized, and shared between groups? Simply aggregating groups that do not have shared discourse practices, norms, and values through a Web site will not achieve the goal.

Which distance learning technologies are appropriate to support such groups? We know that simply putting Internet technology in place will not result in a sustainable, scalable human network.

The report also calls for the development of a national teacher Web portal that includes a "virtual resource center" and a "one-stop-shopping" learning network and that supports interactive, online conversations and meetings. The intent of the recommendation is to imbue a Web portal with CoP characteristics; the challenges in doing so are not well understood. K-12 education vertical portals (Apple Learning Interchange, Education World, Discovery Channel, PBS TeacherSource, to name a few), by design, lack many key characteristics of CoPs, and very few (notably the Math Forum) have been able to establish an active knowledge-building community. Murray (1999) suggests that vertical portals are inadequate as an infrastructure for CoP because "portals must connect us not only with everything we need, but with everyone we need, and provide all the tools we need to work together." Lieberman (1996) points to another missing feature: committed community leadership. Although Web portals provide newsgroups, mailing lists, discussion boards, and chat rooms, none provide the combination of leadership, support services, user-generated content, workspace, services, and ownership that a CoP can provide its members. It is important that research be conducted both to eliminate the confusion between a Web portal and an online CoP and to understand how the two can be mutually supportive.

In their recent book, Brown and Duguid (2000) analyze examples of the failure of information technology to live up to inflated promises. Failure, Brown and Duguid conclude, is related to neglect of ways in which people learn (often from informal interactions with peers), their resourcefulness in solving problems (often drawing on interactions that are difficult to encode in databases), and the communities of practice they participate in (often invisible to an informational analysis). Research cannot continue to treat *community* as a side effect of a TPD intervention or the inevitable outcome of a Web portal or electronic network. We must study online CoP as a valid component of the education system in its own right or risk continuing the same pattern of a few irreproducible successes and many redundant failures as practitioners and providers struggle to keep pace with emerging technologies and the rapidly changing Web landscape.

The Need to Rethink the Role of Online CoPs in Relation to TPD

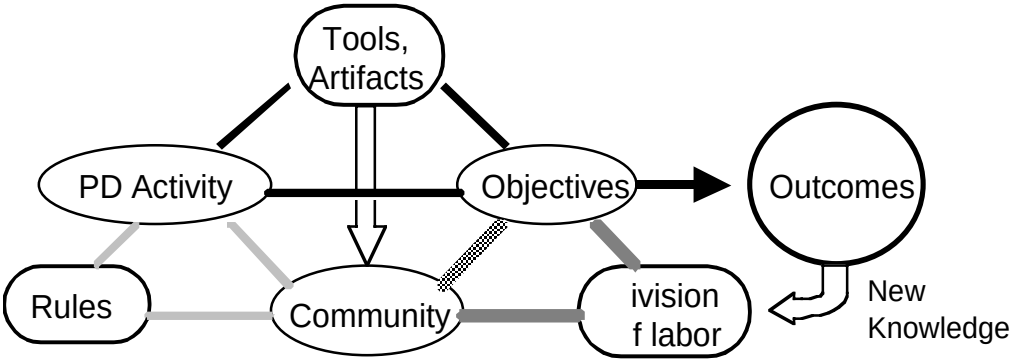
Viewing a CoP as a separate component of an education system, rather than as an outcome of individual projects, places the CoP in a complementary, mutually supportive rather than a subordinate relationship with TPD projects. This relationship enables the CoP to help address practical problems that are shared by most TPD projects (Schlager, Fusco, & Schank, in press). For example, TPD staff (especially in small local projects that make up the majority of TPD efforts) are often expected to be experts in selecting, installing, and managing online technologies, familiarizing teachers with the technology, planning and hosting online activities, and providing on-demand technical support. They must devote precious time and resources to these tasks *in addition to* accomplishing the project's central mission of helping teachers learn new content and pedagogy. In addition, staff are hard pressed to provide the support that teachers need as they return to the classroom after they participate in SMET TPD projects. Members of a mature online CoP form social structures that can help TPD project staff introduce teachers to the online medium, plan and implement online activities, and fill gaps in local resources.

The CoP framework can also support informal TPD activities. After a TPD project ends, the CoP becomes the support structure within which teachers can sustain their collaborative efforts and their nascent collegial community. The CoP can also help teachers who are not fortunate enough to have participated in formal SMET TPD projects take charge of their own professional development (Rényi, 1996; Darling-Hammond & Ball, 1997) by giving teachers access to collaboration opportunities, tools, and support. The reciprocal nature of the CoP-TPD project relationship is a key determinant of the sustainability of the community. Individual TPD projects can become part of a network of TPD resources (both human and information) and a source of new CoP members, which enables the CoP to grow, spread innovation, and reproduce itself (Lave & Wenger, 1991; Barab & Duffy, 2000).

In Exhibit 1, we illustrate the CoP social infrastructure as a modified activity-theoretical diagram (Engestrom, 1987) to help reveal the relationships between individuals, groups, tools, and community that mediate CoP activities (see Blanton et al., 1998, for a discussion of the Cultural-Historical Activity Theory perspective on online teacher education). The diagram highlights inherent limitations in building a sustainable community within individual projects and raises a number of important research questions.

The top triad (indicated by black links) represents a group engaged in a TPD activity, the tools and other artifacts that they use, and their objective, leading to some outcome (the focus of most face-to-face and online TPD research). For our purposes, the TPD activity can be a formal TPD course, an informal discussion group, or some other professionally relevant activity. It may succeed or fail to accomplish its objectives independent from outside influences. Most SMET teacher enhancement projects fit in this part of the diagram. They bring together a previously unconnected group of teachers, use a particular set of tools that have typically not been part of the teachers' prior repertoire, and establish roles and rules that are internal to the project.

Exhibit 1. Representation of the relationship between a TPD project and a community



The bottom row of the diagram highlights the social structures that are missing from most online TPD research and development—the extant community, its rules and social norms, the responsibilities of its members [e.g., community organizers (Lieberman, 1996) and volunteerism (Constant, Sproull, & Kiesler, 1996; Wellman & Gulia, 1999)]—and the ways in which the CoP relates to particular groups and activities. The light gray triad at the lower left represents the relationship between a community's social norms and rules (e.g., work practices, professional values, dispositions toward inquiry, trust, commitment) and those of the particular group engaged in an activity. Members of the community adopt these rules as they participate in the activities of the community. In online discourse, participants must also learn the norms of online communication (e.g., communicating effectively via text chat, leading an online meeting). The community establishes these norms and helps introduce newcomers and new leaders to the techniques used to communicate and share information (Derry et al., 2000; Schlager et al., in press). Having to develop new shared norms and practices on project time can distract the group from the tasks at hand and undermine the goals of a TPD project (Grossman et al., 2000).

The dark gray triad on the lower right connects the community to the objective of the individual group through division of labor, making the success of the activity a community-wide responsibility. As described above, the online CoP can serve as a valuable resource to TPD project staff and participants

through direct assistance, through access to networks of outside expertise, and as a sustainable source of support. This part of the social infrastructure reflects Granovetter's (1973) notion of *the strength of weak ties*, in which the spread of new ideas comes through weak ties between people in separate social clusters. Studies of online communities (Constant et al., 1996) and our own data show that such social support structures enable members to develop the kinds of nonredundant, weak social ties that foster the spread of new information. This triad is also the mechanism through which members of the community with expertise to share can become valuable resources and move toward community leadership roles. Wellman and his colleagues (Wellman, 1997; Wellman & Gulia, 1999) found that people having positive regard for the social system in which requests for assistance are embedded are likely to show respect for that system by offering their help, not only to others who have helped them in the past but also to total strangers. An important research question is how these weak ties develop among members of an education community and how the infrastructure can amplify their power.

The diagram also helps us understand the CoP processes that can support capacity building, knowledge building, and the spread of innovative ideas. The white arrows in the diagram illustrate how the community serves as a memory and dissemination mechanism for ideas, tools, and other outcomes. The knowledge built by individual groups makes its way back into the community in three forms: (1) the new skills and expertise of the members of the group return to the community as those members participate in new activities with other members of the community; (2) the group may create new artifacts (e.g., rubrics, lessons) that become part of the community's knowledgebase; (3) the tools used by the group (e.g., video cases, e-portfolios, modeling and simulation tools) and knowledge of how to use them make their way into other activities (Hoadley & Pea, in press). With no extant community outside the project, new knowledge has nowhere and no way to spread (other than through formal dissemination mechanisms that are slow and/or costly). We emphasize that these same mechanisms can also foster and spread dysfunctional norms (Ball & Cohen, 1999) and ineffective practices. For example, a recent article about New York City Schools (Hartcollis, 2000) suggests that "beneath the veneer of civility, teachers at this school and elsewhere say the system has failed to create a culture in which they all feel like part of a team, where older teachers feel valued and younger ones see a future." An important research question is whether and how the social structures of an online CoP can help its members unlearn the dysfunctional norms that are prevalent in school culture today and learn to function as an effective, supportive professional community.

Evidence of Online Education Communities of Practice: Guideposts for Research

Aspects of this online CoP framework are being explored in a handful of teacher education and professional development research and development projects. For example, the Inquiry Learning Forum (ILF) project at Indiana University and several PT3 grants are focusing on building community among preservice and inservice teachers. The ILF is designed around a "visiting a classroom" metaphor. Videos and discussion forums act as anchors to a variety of support materials, including teacher reflections, lesson plans, links to standards, resources, and student work (the PI of this proposal is on the ILF Advisory Board). The LiNC and MOOsburg projects at Virginia Tech (Carroll, Chin, Rosson, & Neale, 2000) focus on building community at the school and district levels. Researchers are working directly with school administrators and teachers at a single school to learn how best to support standards-based reform. They use multi-user virtual environment (MUVE) technology along with productivity tools to support group work and foster community. Several practitioner organizations, TPD providers, and even commercial vendors are also taking steps to implement online CoP concepts in support of local and large-scale TPD efforts (Schlager, Fusco, & Schank, 1998; Firestone & Pennell, 1997). For example, the Newport News Virginia Student Teacher Excellence Professional Community Urban Systemic Initiative project is explicitly modeling its online community after the TAPPED IN model (see below). AEL Inc. is focusing its online CoP efforts on the regional level through its Eisenhower Regional Math and Science Consortium (see letter of support). Efforts such as the Math Forum, PBS TeacherLine (TAPPED IN tenants) and the National Writing Project are addressing a national audience within a particular content domain. Finally, Canada's SchoolNet, the European SchoolNet, and several other national SchoolNet projects around the world represent efforts to establish large-scale omnibus online CoPs for education professionals.

We have developed an exemplar of an online CoP called the TAPPED IN Testbed project (http://www.tappedin.org; NSF CDA-9616585, REC-9725528). Over the past 4 years, we and our partners

have conducted research and development aimed at understanding the nature and affordances of online CoPs in the service of TPD and systemic reform projects (Schlager & Schank, 1997; Schlager, Fusco, & Schank, 1998, and in press; Fusco et al., 1999; Derry et al., 2000). We have been quite successful at cultivating a thriving community that reflects the activities of all three of the triads in Exhibit 1. Through TAPPED IN, more than 8,500 K-12 teachers, librarians, teacher education faculty, professional development staff, researchers, and other education professionals can attend activities hosted by education organizations, conduct their own activities, take online courses, bring their students online, experiment with new ways to teach, or expand their circle of colleagues by participating in community-wide events.

TAPPED IN helps to knit together and fill in the gaps between isolated TPD projects by offering TPD projects a *shared* online environment where each can engage in its own online activities but share expertise, resources, and technical support. Currently, 17 *tenant* organizations have their own spaces in the community environment where they conduct online activities. Scores of other organizations, classes, and small groups use TAPPED IN facilities and support services on an as-needed basis for special events, seminars, and workshops. Several university faculty incorporate TAPPED IN into their courses or teach an entire course through TAPPED IN.

TAPPED IN has demonstrated a scalable social infrastructure for supporting the online activities of a large community, which has been adopted and evolved by the members themselves. For example, we initially felt that greeting people was an important first step in welcoming new people into the community. We established a live Help Desk in the reception room, staffed by members of the research team, to help users get oriented to the system. Today, the Help Desk is staffed primarily by teacher affiliates, interns, and volunteers who donate their own time. Approximately 12 hours a day, these community members answer questions, offer tutorials, and give tours in real time to the hundreds of guests and new members (400-500 on average) who log into TAPPED IN each week. Help Desk staff and volunteers also help TPD project leaders quickly and effectively plan and conduct online activities, often in conjunction with face-to-face activities and other online technologies.

Our *After School Online* (ASO) discussion series is another integral part of the community infrastructure. ASO sessions are hour-long, real-time discussions on topics suggested by the community and led by volunteers recruited from the community. Education organizations and outside service providers also hold ASO sessions to publicize their projects and interact with teachers in a conversational format. Topics for the month are announced to all members via an e-mail newsletter (which is disseminated by members to listservs around the globe) and on a Web calendar. ASO was originally conceived of as a venue for our partner organizations and leaders in the community to reach out to teachers by sharing content and strategies in an open, informal forum. Over time, it has grown into a way for members to meet other members with similar interests, to gain comfort with the technology, and to develop online discourse skills in a low-pressure, motivating context. ASO has also provided an authentic way for members to learn how to host their own seminars and lead their own groups in online discourse. As a result, we have seen an increasing number of members start their own *spinout* seminars (e.g., social studies, science, art, and technology discussion groups) that meet weekly or monthly. Thus, TAPPED IN not only helps educate teachers but also incubates teacher-leaders and teacher-led innovation.

Today, Help Desk and ASO are our primary means of helping build the capacity of the community members to develop their own activities, shared values, and identity. By using the Help Desk and attending ASO sessions prior to the start of a TPD project, project participants learn the skills and norms they need to interact effectively online, thereby enabling the teachers and TPD staff to focus on learning content, not learning to communicate. Because TAPPED IN does not shut down when a project ends, we can provide continuing support to teachers whose TPD project has come to an end. More importantly, because TAPPED IN is open to any K-12 education professional, those who are not fortunate enough to participate in formal projects can interact with those who have done so and with other education professionals outside of their local confines. They can learn about new ideas and emerging technologies as professionals in other professions do—through informal networking with colleagues.

Together, the research and development efforts that we and others are conducting are beginning to reveal the online activity structures, communication channels, services, and tools needed to support effective CoP-based TPD practices. They are beginning to document who participates in online education CoPs, how frequently, and why; how an online CoP works to support individuals, groups, and

organizations; and how online education CoPs grow and evolve. They are just beginning to learn how to measure the effects that participation in online CoPs has on teachers' collegial relationships, professional growth, and classroom practices (Blanton, et al. 1998; Lieberman & Grolnick, 1999). As a research community, we have a long way to go, and the challenges that we face are compounded by the rapid pace of change in Internet technology.

The Need to Rethink the Design of Technical Infrastructure for Online Education CoPs

With a growing online community made up of a rich fabric of activities, experience levels, sources of support and expertise, and leadership, we are poised to embark on a new phase of research that would not be possible without the existence of TAPPED IN as it is today. We are beginning to address the social aspects of teacher learning that are the focus of ROLE Quadrant 2 as well as the "complex systems of practice" that are the focus of ROLE Quadrant 4. For example, we have a small NSF grant to develop research methods needed to collect and integrate evidence of three indicators of practice and learning that research has shown to be key to the success of online communities: discourse practices (Woodruff, 1999), shared values (Louis, Marks, & Kruse, 1996), and identity development (Donath, 1997; Wellman & Gulia, 1999; Rogoff, 1996).

We have built an online environment that supports some of the key activities of an online CoP, but the environment does not support other online structures and activities that we know are needed to move forward with our research. To enable the processes and measure the benefits of an online CoP, we must rethink not only the socio-organizational structures of the community but also the technical infrastructure (Bringelson & Carey, 2000; Brown & Duguid, 2000). As Hawkins (1996) advised, we will not realize technology's promise as "the backbone for an invigorated, vibrant professional community among educators…without considerable effort to design the technologies and the social structure of their use with this objective made explicit."

Why not continue to build on our current infrastructure? We constructed the current TAPPED IN multi-user virtual environment (MUVE) from a descendant of the LambdaMOO server (Curtis, 1992) because it was the most appropriate technology available 5 years ago to satisfy a set of design requirements that are still applicable today (described in the next section). We have found the MOO to be a very useful exploratory research platform, and we are pleased to see that the platform has gained recognition in the mainstream higher education community (Haynes & Holmevik, 1997; Young, 2000). Although we could continue to patch in new capabilities, we believe that the MOO platform has reached the end of its useful life as a research and development infrastructure, for two reasons.

The first reason concerns the ROLE theme of promoting the use of new and evolving technologies and "systems development that can lead to significant advances in understanding…." The MOO server architecture is a closed, single-threaded, text-based system that was not designed to support some of the capabilities that our research has found to be central to our ability to extend our online CoP framework. If we continue our research on this platform, technology limitations will constrain our efforts to develop guideposts to the future. To continue to conduct leading-edge research, we must shed the limitations of the MOO platform, retain the capabilities that we have found useful, and build on more powerful, flexible, and scalable technologies that are now available (see Schank, Fenton, Fusco, & Schlager., 1999, for a more complete discussion of the technical affordances and limitations of the MOO platform).

One example of why we must keep pace with emerging technology as we continue our research is the trend toward online audio communication. We know from our work in the text-based medium that different pedagogical contexts (e.g., a lecture versus a study group) can place different technical demands on a system. A desire to recreate a common face-to-face social dynamic in which a speaker lectures and then takes questions has led several TPD leaders to ask us for an "auditorium" mode of communication, which would technologically restrict participants' ability to talk publicly while allowing a speaker's comments to be broadcast to the entire audience. The requests are based on concerns that people will not follow face-to-face social norms in an online venue, and the dialogue will get disorderly and unwieldy. Our research has enabled us to successfully resist such requests on pedagogical grounds, and to rely instead on developing social norms and technological features that do not restrict communication, but rather support socially appropriate dialogue (e.g., whispering, group tables, and text-based whiteboards).

New challenges are introduced when we move to audio-based communication. Two types of Internet-based voice communication are now available: broadcast and peer-to-peer. TAPPED IN users are experimenting with both types of systems and asking us for our recommendations. The choice between the two has been frustrating for TPD project leaders who want to encourage small-group dialogue but also want to hold large online lecture format events. The problem is that current systems do not support both broadcast and peer-to-peer audio modes well, placing a priori restrictions on communication. Thus, our infrastructure will have to support a new stage of research on effective discourse models and features for using the new audio technologies. Other emerging technologies (e.g., streaming video, user profiling) that are potentially beneficial to an online CoP raise equally important issues. If we cannot support emerging capabilities, our findings will reflect past constraints, not opportunities for innovation.

The second reason to move away from the LambdaMOO platform speaks to the ROLE themes of human capacity development and transferring research products into practice. The LambdaMOO programming language is not taught in university computer science departments or used outside a small circle of MOO *wizards*. We have been fortunate to have one of those wizards on our team from the beginning, but we do not encourage our other programmers or student interns to learn to program in MOO because it will not serve them in their careers. Moreover, we have a responsibility to consider the technology transfer implications of our work. Over the past year, we have received several requests for copies of our server by universities and organizations in the United States and around the world (Italy, France, Japan, Korea, Spain, Singapore) wanting to establish their own online CoPs. We have had to discourage them from using our platform (or any MOO-based platform), explaining the difficulty they would have in finding qualified system administrators and programmers to manage and upgrade it. Consequently, neither we nor our partners think it prudent to continue building on the MOO platform.

Why not use a commercial MUVE platform? When we set out 4 years ago, we were convinced that a commercial MUVE development platform that would meet our design requirements was just around the corner. Despite a great deal of development in labs and by commercial developers, no MUVE platform today meets what we (and most TPD practitioner organizations that we talk to) believe are the requirements for an online education CoP, For example, colleagues have asked why we do not use one of the two most popular 3D virtual environment platforms, The Palace or ActiveWorlds. The technical reasons why such environments are inappropriate are described in Schank et al., (1999) (e.g., not programmable, platform dependent) and illustrated by the following episode. We were recently contacted by one of the developers of ActiveWorlds' education world. She had conducted a comparison of ActiveWorlds and TAPPED IN when the teachers in an NSF-funded Teacher Enhancement project on which she was consulting complained that ActiveWorlds was not meeting their needs. She concluded that ActiveWorlds did not have the discourse-support features needed to engage in meaningful professional discourse, and she recommended that the project move into TAPPED IN (anonymous personal communication). Several organizations that now use TAPPED IN reached the same conclusion after comparing TAPPED IN with other platforms (e.g., WebCT, Pepperdine, NCREL , and PBS). (We note that the vendor of The Palace recently went out of the MUVE business.) Finally, we have also been asked to be a beta tester of Microsoft's new V-Worlds MUVE platform technology (Vellon, Marple, Mitchell, & Drucker, 1998). When asked questions regarding their development plans (e.g., when they will support Macintosh users, a large percentage of our community), they could not provide answers that would satisfy our research goals.

Who will use and benefit from the new infrastructure? Tens of thousands of individual educators (members and guests) have already experienced our CoP framework and our technology. Dozens of nationally-recognized education organizations and many more local education agencies and groups have used the TAPPED IN MUVE. Several organizations in the United States and several other countries (e.g., AEL, Newport News USD NSF project, eASEAN SchoolNet, Piedmont School Network in Turin, Italy) are currently applying the TAPPED IN CoP model to cultivate their own online communities. Researchers have used TAPPED IN as an exemplar in their writings (e.g., Bringelson & Carey, 2000; Dede, 2000; Riel, 2000), and more than a dozen graduate students around the world have conducted research within the environment (e.g., Cerratto & Waern, 2000; Gray, 1999; Derry & DuRussel, 1999; Kim & Derry, 2000; Steinkuehler, Derry, & Kim, 2000; Polin, 2000; Reuss, in progress; Johnston, in progress). Education faculty at both large and small institutions of higher education (e.g., Pepperdine, George Mason, Harvard, Michigan, Michigan State, University of Illinois, Indiana University, University of British Columbia, Georgia Tech, University of Virginia, Gannon College, California Lutheran, California State Long Beach,

Sacramento, and Hayward, and others) have exposed their students to online CoP concepts and experiences through TAPPED IN. Senior TAPPED IN staff also serve as advisors and consultants to several leading education agencies and organizations (e.g., AEL, PBS, Unext, TeachScape, WebCT, Indiana University, Lawrence Hall of Science, Los Angeles County Office of Education).

In accordance with the ROLE themes of *Research Transfer* and *Human Capacity Development*, we will continue our highly successful practice of welcoming practitioner groups and researchers into our community, and we will also make the infrastructure available to other research and practitioner groups to support their own community development work. We expect that our current user organizations (most are themselves NSF grantees) and the teachers with whom they work will continue to apply our models and use our infrastructure for research (e.g., ROLE projects in Quadrants 2, 3, and 4; IERI; PT3) and implementation projects (e.g., NSF Systemic Initiatives and Teacher Enhancement projects). We will also continue to serve (and learn from) large and small teacher education and TPD programs outside the NSF umbrella to enable our research findings to make their way more quickly into practice on a national scale. In addition, our effort will help inform other education technology researchers through new design principles and guidelines that are specific to online education CoPs. As described above, most current design principles for technology to support teacher communities have been developed in the context of design experiments on specific pegagogical interventions (e.g., Brown & Campione, 1990; Dunlap, Neale, & Carroll, 2000; Marx et al., 1998; Putnam & Borko, 2000). Consequently, they lack sensitivity to key issues that are central to CoP-based teacher professional development, including scalability, sustainability, awareness, identity, multiple content domains and pedagogoies, self-directedness, anywhere-anytime access, social networking, and lifelong learning (see Bruckman & Resnick, 1993; Schank et al., 1999; Kiesler, 1997; Smith & Kollock, 1998). We believe that this mismatch has led many education research and implementation projects to apply inappropriate design concepts based on misconceptions about the structures, affordances, and constraints of online communities of practice with disappointing results.

Project Approach

We will adopt a participatory, scenario-based design approach (Nardi & O'Day, 1999; Carroll et al., 2000) to develop our prototype infrastructure. Nardi and O'Day (1999) argue that successful design of a new information technology is best pursued within a community setting in which stakeholders are empowered to discuss the technology. The most successful designs involve diverse participants with common goals and values. In accordance with this view, our approach to development brings together a design team representing researchers, teacher educators, technology developers, regional education support providers, national TPD organizations, and our core constituency, TAPPED IN members (see Project Staff below). The team will also include experts in Web-based development and graphical user interface design.

As members of the TAPPED IN research and development community, our team members have already demonstrated that they share a common vision based on the CoP framework described above. But the members bring different perspectives, goals, and self-interests that will benefit the project. We emphasize that the proposed project will accomplish only the first steps in a long-range research and development agenda: prototype design and development. The partners in our project plan to apply the outcomes of the project in their own online systems, programs, or research (see letters of support). Thus, our approach will rapidly translate our effort into useful, actionable results for practitioners, policy-makers, commercial developers, and teacher education and TPD providers (Kling, 1999), as well as our own continued research.

Task 1. Specify the Design Space (Pre-award through Month 1)

Our decision to design through user scenarios is derived from the need for a multidisciplinary team to address a dauntingly large design space. Several categories of technology have been linked to online TPD and CoP research. *Communication technologies* support the core discourse practices of a CoP, which establish and spread social norms and build the knowledge of the community. The CoP infrastructure should support multiple styles and modalities of synchronous and asynchronous communication that enable group members with different styles of expression to participate fully in group discourse (Dede, 2000). *Authoring and presentation tools* are used to create pedagogical structures (e.g., course syllabus, roster, reading list) and support online discourse (e.g., shared Web pages and whiteboards, lesson plan and assessment authoring tools). *Archival tools* are meant to support storage, organization, and mining of CoP

knowledge (e.g., member profiling, digital libraries, personal and group information filing). *Virtual workspaces* are places where (a) groups can meet online, conduct private activities, and store artifacts and (b) the CoP can conduct public events and provide community services. *Data collection and management tools* enable researchers and evaluators, as well as instructors and TPD project leaders, to track participation and discourse patterns. Although not part of the infrastructure, *pedagogical and content tools* (e.g., data visualization, modeling and simulation, and embedded assessment tools) and *documentary tools* (e.g., e-journals, discussion transcripts, digital video clips, e-portfolios) must be part of the SMET TPD curriculum. Therefore, the CoP infrastructure should enable interaction with these types of tools.

The first task of the design team will be to review our current assumptions on the design space in preparation for scenario development. We and our partners have already begun to specify a range of user profiles, pedagogical approaches, and support/administrative roles (Exhibit 2) and a first-approximation technology feature set (Exhibit 3).

Exhibit 2. Initial set of roles, services, and TPD approaches.

Roles	**Community Services**	**TPD Approaches**
• New member	• Help desk	• Formal courses
• New instructor/leader	• Event publicity, facilitation	• Informal seminars & groups
• TPD staff	• Resource and expertise brokering	• One-on-one problem solving
• Community organizer	• Community leadership	• Project-based collaboration
• Researcher	• Support for staff and students	• Observing and modeling
• Expert resource	• Activity design consultation	• Try out new tools, practices
• Volunteer	• Member and content database	• Demonstration/presentation

Exhibit 3. Initial set of CoP infrastructure features.

Communication	**Administrative & Research**
• Text chat, whisper, paging/instant message, emoting • Peer-to-peer voice/video (e.g., ClearPhone) • Broadcast voice/video (e.g., HorizonLive) • Threaded discussion • E-mailing lists	• Administrative interface • Researcher interface • Data collection/logging/querying • Member profile API • Branding (login, membership, banner ads) • User-configurable client
Activity and Resource Management	**Persistent Virtual Places and Objects**
• Member accounts and privileges system • Member database and profile • Member search • Document storage and search • Asynchronous discussion hyperlinking • Targeted e-mail • Event calendar linked to user profiles • Meeting scheduler • Recommendation engine	• Private places for individuals, groups, and organizations • Public places for events and services • Text and graphical document generation • Web page and streaming video projection • Dialogue transcripts • Text whiteboard • Sketchpad/share drawings • Small group coordination

Task 2. Develop Scenario-Based Design Specifications (Months 1-8)

Exhibit 4 represents a collage of several different user scenarios that we have drawn from actual TAPPED IN users. Our aim is to illustrate the range of activities, contexts, roles, and support structures that we must consider in designing a technology infrastructure for online CoPs. The right column lists some of the major features (technological and social) that support the members of the CoP (for space considerations, we do not list all the features). Some of the features exist today in TAPPED IN and other systems, and others do not. To start a dialogue from with the design specifications will be derived, each member of the design team will develop prototypical user scenarios based on their own perspective and present them to the group. As a group, we will converge on a set of anchor scenarios that reflect the basic

roles, structures, services, and activities of an online education CoP, and develop the functional and architectural specifications of a system that will support those scenarios.

Exhibit 4. Collage of user scenarios

Scenario	**Major Features**
Michael is a middle school math teacher who has been a member of TAPPED IN for a year. He was introduced to TAPPED IN through an online master's degree program. Each of his courses has an online syllabus, reading list, and threaded discussion forum created by the instructor of the course. His cohort also conducts real-time seminars with instructors and visiting scholars, as well as informal study group meetings. Michael also has his own virtual office, where he keeps the artifacts used in and from his course assignments. He has created several file cabinets and folders in his office to organize information (documents, outside readings, transcripts, links to Web sites, and postings). He particularly likes the ability to bookmark discussion board postings and save the bookmark in his own filing system. His personal filing system has helped him quickly refer back to key points in prior course discussions held months ago, which in the past were lost forever. Michael and his colleagues like their virtual offices and prefer to take turns meeting in each other's office rather than in the course classroom. Michael likes the feeling of having his *stuff* close at hand when the discussion gets hot. He also feels that the office reveals a bit of his own identity to his colleagues. He is glad that when he finishes this course and his degree, he'll still have his office and all the important resources it holds. A requirement for Michael's degree is an action research project. Michael chooses to introduce his students to data visualization tools. He recalls attending one of TAPPED IN's monthly Mathematics Discussion seminars a few months ago about component-based software lessons linked to math curriculum. He finds the transcript of the session in his "cool ideas" folder and decides to contact the seven other participants from the session to see whether they have created or used any of the lessons. He also decides to seek out others with similar interests to see whether they want to collaborate. He searches the TAPPED IN member directory to find other mathematics teachers at his grade level who expressed an interest in visualization tools in their member profiles. Michael finds 38 teachers who match his criteria. He uses TAPPED IN's dynamic mailing list (DML) feature to send an e-mail asking whether they are interested in collaborating and planning an online project for their students. The DML feature allows members to e-mail other members while keeping their addresses private. Michael is pleased that three teachers respond and want to collaborate and seven others want to hear the results of their efforts. Because none of the four has brought students into TAPPED IN, much less orchestrated an online project, they seek assistance from the TAPPED IN Help Desk. The Help Desk attendant suggests they review the Student Activities Guide for ideas and to learn what data collection tools are available. Three weeks, four online meetings, and many e-mails later, Michael and his three colleagues have designed a project and assessment rubric for their students using an ESCOT/Math Forum Problem of the Week. The four classes will compare their calculations and results using the shared TAPPED IN drawing board, and discuss online how and why their results differed. The students receive transcripts of the discussion to help them reflect on the session. After the project is over, Michael and his three new colleagues agree to leave the TAPPED IN instant message box open on their computer to engage in quick *water-cooler* chats between classes. It's energizing to Michael to see what others are doing online and in their classrooms.	Course management Meeting scheduler Integrated synch. & asynch. communication Group and personal tools and workspaces Document storage, sharing, searching, filing Permeable course and personal spaces Knowledge management Customization Integration of discourse support artifacts. Identity support Permanent ownership Facilitated online seminars Events Calendar: personalized views of activities with reminders Member directory that is extensible, searchable, and easily integrated with other services Profiles updated by members or automatically based on activity Dynamic mailing lists Savable searches Student accounts Automatic data collection and analysis tools via web forms, tables, graphs, etc. Authoring tools Sharing, viewing, and editing of graphical data in real time Transcripts automatically emailed as record of work Awareness and messaging option: who's connected, buddy lists

We will accomplish this task through a series of monthly design meetings. The first meeting will be held face-to-face, and the balance will be conducted online, at first using technologies that we are considering for inclusion in the infrastructure, and later the prototype system itself. Between meetings, SRI staff will

work to distill and integrate specifications and develop alternative design solutions represented as storyboards, mock-ups, and prototype software. The artifacts and dialogue of the meetings will also be compiled, organized, summarized and made available publicly on the project Web site (see http://www.tappedin.org/info/design.html for an example of our 1998-99 redesign).

As the design takes shape, we will begin solicit requests for comments from the broader research community through the CILT Teacher Learning Working Group (two members of the project team are members of the group) and Knowledge Network (www.ciltkn.org) and from practitioner communities (ISTE, SITE) through their organizational leadership. Individuals, organizations, and agencies in the current TAPPED IN partner community will also be invited to participate in the dialogue. The deliverable of this task will be an evolving, annotated Specifications Document (Web-based) that is hyperlinked to scenarios, design artifacts, discussions, and commentary.

Task 3. Develop Prototype System (Months 2-12)

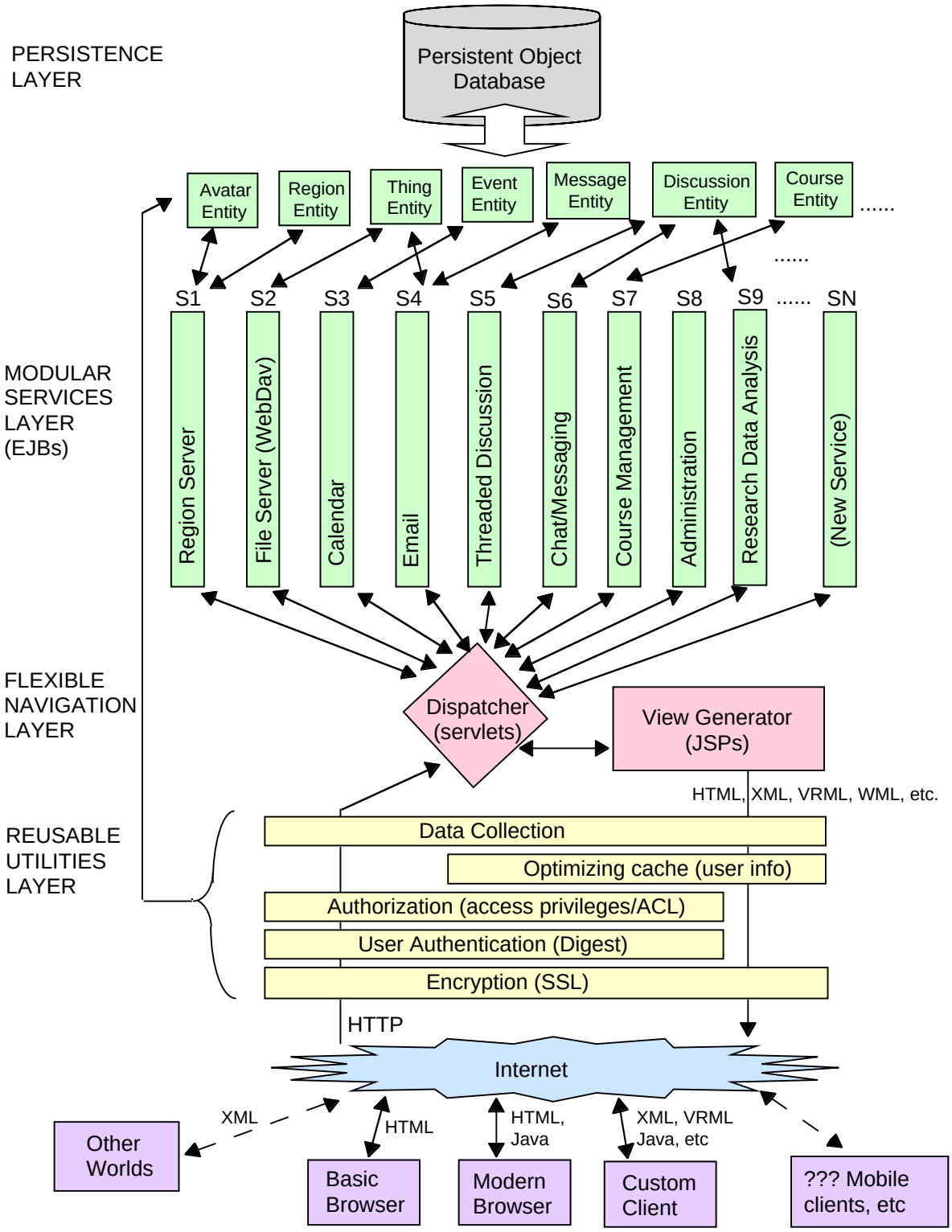
The process of iterative, rapid prototyping will begin immediately after the face-to-face design meeting (well before the specifications have been completed). The basic design will be modular to enable us to plug in new capabilities as they emerge. We have developed a general framework for the system architecture, which consists of a persistence layer, services layer, navigation layer, and utilities layer (Exhibit 5). This design will allow graceful integration of new clients (e.g., mobile devices) and enable future expansion to a distributed network of multiple servers. The persistence layer will use conventional commercial (or open-source) relational database technology, but will be designed to abstract operations so that alternative relational or object stores could be used as advances in database technology (e.g., speed, scalability) occur. The services layer is designed to be very modular (e.g., using Enterprise JavaBeans) such that we can add and take away services to accommodate a given task.

Each month, the design team will meet to decide on design options, discuss the progress on the prototype, and demonstrate newly developed features. Initial specification development will focus on the database, region server service, dispatcher, and authentication. This specification will be implemented in an initial prototype that will support simple authentication and one or two clients. Once these features are implemented, we will incrementally add utility layers and identified services. Additional clients will be developed and supported separately as demand requires. We will publish APIs so that others can also develop clients to work with our environment. The deliverables of this task will be a beta version of a research infrastructure prototype and a Web site documenting the design alternatives, development artifacts, and decision-making rationale.

We will most likely use a combination of proven commercial technologies, open-source software, and custom-designed technology. The decision of whether to use existing technology, build our own, or forgo a particular feature will be a central part of our design process. The navigation layer is designed for flexibility and will be custom built. The navigation logic will be easily modified through logic tables rather than program code, to facilitate maintenance. The role of the dispatcher will be to send requests among the services, relieving the services of any responsibilities for workflow (i.e., enabling division of labor). At the same time, the dispatcher responds to the client (user-agent) by sending the service response to be formatted by the proper view generator (using Java Server Pages). For example, a custom client may receive XML while a simple Internet Explorer browser receives HTML for the same service. The global utilities layer includes tools that are reused across many services, and much of this layer will also be custom built. For example, each service will require authentication; each person must identify him/herself as a registered user to access that service. By sharing a global tool for this purpose, we reuse code, reduce labor, and increase modularity and uniformity between services.

How will we decide whether to use existing technology or build integral services? Several commercial technologies satisfy overlapping subsets of our CoP research infrastructure requirements. For example, groupware such as Webex, Placeware, HorizonLive, and Astound support real-time multimedia presentations and small-group meetings. Web-based discussion tools such as O'Reilly WebBoard and eGroups enable anyone to set up asynchronous discussion forums, mailing lists, and chat rooms. MSN and AOL have instant messaging services that provide awareness of who is online and the ability to chat. Some systems enable broadcast audio, and others enable peer-to-peer audio; others support live and/or recorded streaming video; still others provide server space for storing files. The main obstacles in using commercial technologies to build an integrated CoP research infrastructure are (a) a lack of interoperability (such as

Exhibit 5. Infrastructure architecture diagram



different operating system and client-side requirements: e.g., HorizonLive runs only on a customized Linux server), (b) the proprietary nature of the systems (which precludes us from modifying the source code), and

(c) the licensing cost. For example, HorizonLive licenses start at $12,000 per year for 10 seats. WebEx, Placeware, and Astound cost $400 to $2,000 per seat per year.

Consequently, we are seriously evaluating open-source technology. For example, ArsDigita is a comprehensive Web-based community toolkit. However, its use of the TCL language, which is no longer widely used, and its vendor-specific technology limit its applicability (the developers are rewriting aspects of the system in Java). We are currently exploring whether we might use the Virginia Tech CORK MUVE architecture (Isenhour, Rosson, & Carroll, in press) in our system. CORK appears to have many of the features that we need, and we would be able to build new capabilities as needed. For example, CORK offers a useful peer-to-peer state sharing mechanism by replicating objects on the client and server. But because our framework does not require Java on the client, we would limit our use of CORK to support object replication on the server side. Unlike the CORK/MOOsburg system, our framework is designed to maximize accessibility by supporting a variety of clients—no special software or installations will be required for participation beyond a basic browser. (Requiring installation of special software is a significant usability barrier; Nielson, 2000.) The PI of this proposal (Schlager) and the PI of another ROLE proposal by Virginia Tech (Carroll) have agreed to serve as consultants on each other's projects to facilitate sharing of information and code. One area in which we are likely to use a commercial system is online course management. WebCT and Blackboard are by far the leaders in this space. We believe that the capabilities they provide are a necessary part of our infrastructure, and we do not consider it cost-efficient to build a set of features that could rival these commercial platforms. We have talked with both companies and chosen to partner with WebCT because it shares our CoP philosophy (see letter of support). WebCT developers also recognizes the gap in their system in this area, and they are currently conducting user community tests in TAPPED IN to determine the viability of future co-development.

Task 4. Pilot Test Prototype with Users (Months 13-16)

Our approach to iterative user testing and debugging new capabilities or user interface modifications in the TAPPED IN project has been to set up a shadow system accessible from a test Web site. We then invite members of the community (usually community leaders) to log into the system and give us their initial impressions. Often, a member of the design team captures the experience in real time through an online interview. Other users send us their comments via e-mail. When the major bugs are found and resolved, we conduct actual events in the test system. We will continue this approach to test our new infrastructure. Members of the TAPPED IN community, ISTE members, and others who have participated in the design dialogue Web site will be invited to "test-drive" the prototype and provide feedback via the project Web site. We will also conduct pilot events in the prototype that reflect each of the major scenarios. Design issues raised by the tests will be discussed and resolved at the monthly design meetings.. Deliverables will include documentation of user feedback, discussion of design issues, and artifacts of changes made to the prototype.

Task 5. Establish Partnerships for Further Research and Development (Months 7-16)

Our first NSF-funded pilot project 4 years ago set the stage for lasting partnerships with other research and TPD provider organizations (e.g., Lawrence Hall of Science, Math Forum, National Center for Science Education, Pepperdine University) that have benefited our research and their programs. The proposed project will again serve as a springboard for forming new partnerships that will support a wide range of online CoP research with innovative online TPD pedagogy, emerging tools, and complex social structures. It will also lead to partnerships designed to help sustain the research testbed community and advance the development of the technology, both of which are necessary preconditions of the research. Specifically, we will seek mutually beneficial partnership and licensing arrangements with our project partners and other researchers and TPD providers for their own projects. The outcome of this task will be several new NSF research proposals and sources of funding needed to continue community operations and development.

Project Staff and Resources

SRI has assembled a highly qualified and experienced team of researchers, developers, and outside experts for this project. We will make use of SRI's extensive technical support and Internet facilities (see SRI Facilities section), as well as equipment provided by Sun Microsystems, WebCT, and other vendors (at no cost to the proposed project).

Dr. Mark Schlager, Center for Technology in Learning Associate Director of Learning Communities, will serve as Principal Investigator, providing overall leadership and coordination. Mark's online collaboration research over the past 15 years has spanned industry, government, and education. He is currently the PI of the TAPPED IN Testbed project. **Dr. Patricia Schank,** architect of the current TAPPED IN system, will serve as Co-Principal Investigator. Dr. Schank's research focuses on the design, development, and evaluation of computer-mediated learning environments. She will co-direct the development effort (with Jamie Fenton), focusing primarily on client and user interface technologies. Other senior SRI staff on the project are **Jamie Fenton,** Senior Research Engineer, who will be responsible for server and networking technology, **Dr. Judith Fusco**, Research Scientist and TAPPED IN's Director of Online Community Research, who will represent the TAPPED IN user community in the design process, and **Dr. Christopher Hoadley**, Research Cognitive and Computer Scientist, who will lead the development of knowledge management features. **Aaron Becker**, a freelance Web graphic designer brings expertise in concept creation, storyboarding, editing and compositing, texture mapping and lighting, and animation. **Kari Craig,** a computer science student, will be responsible for capturing design artifacts and designing and managing the design process documentation Web site.

Our design team will also include representatives of our partner organizations and user community.

B. J. Berquist is an art teacher in Pennsylvania. As a TAPPED IN Associate Educator, BJ is responsible for publishing the monthly newsletter and organizing the After School Online Schedule of Events. She brings this experience and the perspective of an online community leader to the project.

Aaron Bond, Manager of Community Integration at WebCT, brings the commercial developer perspective to the project. Aaron is responsible for the integration of the WebCT course platform and the WebCT.com e-Learning Hub. He also manages the development of the WebCT network of communities, in which members share ideas and resources for teaching and learning online.

Dr. John Carroll, Professor of Computer Science, Education, and Psychology and Director of the Center for Human-Computer Interaction at Virginia Tech, brings expertise in participatory scenario-based design methodology, technology to support collaboration, and community computing to the project. As principal investigator of the MOOsburg project, he will also bring valuable experience in the development of Java-based multi-user virtual environments.

Stephan Knobloch, Director, PBS TeacherLine Certificate Program (www.pbs.org/teacherline), represents the needs of a national mathematics TPD program. The PBS TeacherLine project is a partnership of PBS, NCTM, 16 local public TV stations, and several education agencies that is providing online learning modules for teachers. PBS is responsible for developing the Virtual Professional Development Academy.

Dr. Tammy McGraw, Director of Technology and Innovation at AEL, Inc., is responsible for implementing AEL's online communities for the SouthEast Initiatives Regional Technology in Education Consortium (SEIR*TEC) and the Appalachian Eisenhower Math and Science Consortium, which involve thousands of education professionals in several states. She also brings extensive experience in public schools, as a classroom teacher and technology director.

Dr. Linda Polin, Professor of Education and Director of M.A. and Ed.D. Programs in Educational Technology at Pepperdine University, has pioneered online teacher education through one of the leading online degree programs for education practitioners. As a current tenant of TAPPED IN, she will advise the project team on design issues related to tools and services for teacher learning in a university context.

Dr. William Spitzer, Director of Education at the New England Aquarium, is responsible for development, delivery, and evaluation of institutional education programs and exhibits that reach more than one million Aquarium visitors, and thousands through outreach to youth and community organizations and schools. He will represent the perspective of museums as Informal Science Education organizations.

Dr. John A. Vaille, Chief Executive Officer of the International Society for Technology in Education, will advise the project on design of technology and services from the perspective of the technology-using education practitioner community and provide user groups to review and comment on our design.