

TeacherBridge: Knowledge Management in Communities of Practice

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ABSTRACT

The TeacherBridge (**B**asic **R**esources for **I**ntegrated **D**istributed **G**roup **E**nvironments) motivates collaboration and supports online tools for teachers' professional resource management by providing a socio-technical infrastructure for community networks. While this project focuses initially on local science and mathematics teachers, resources developed are designed to be globally diffused to a wide variety of online communities. This paper discusses the characteristics of online communities of educators and how home networking technology and knowledge management systems can support collaboration and knowledge sharing in such communities. We study examples of existing and well-known online communities of educators and introduce our own system, TeacherBridge, which supports teacher professional development by supporting peer-based collaboration and community. We also analyze and evaluate the characteristics of TeacherBridge with activity theory [12] and minimalism [37]. Activity theory provides an analytical framework for how TeacherBridge can be used as a socio-technical infrastructure for online communities of educators; minimalism guides the development of successful online communities that are easily accessible and facilitate teacher participation in knowledge sharing activities

Keywords

Knowledge management, online communities, virtual communities, home networking, community networking, minimalism

1. Introduction

Information technology has redefined our notion of 'community.' What was once considered the most common feature of all human communities—that they are made up of people who live together—has now been replaced by alternative interpretations of unity, group, and community. The now-common terms 'online communities' or 'community networks' are used to describe self-organizing

groups whose members might live or work in dispersed geographical settings but who still possess common interests, share knowledge, and take part in unified learning experiences. Such communities bring many potential benefits: enhanced and mutually-beneficial support and communication among members; the sharing of best practices, including a broad range of knowledge, common interests, and feelings; and the creation of powerful environments that enable social and intellectual connections.

However, the act of achieving a successful community for promoting communication, improving social interaction, and increasing productivity poses serious challenges, particularly in terms of innovation. The main challenge facing online community technology is how to best enable members to communicate, collaborate, and coordinate so as to facilitate knowledge capture and utilization. In fact, some segments of society remain highly resistant to the concept of collaborating and interacting online, so the problem becomes especially acute when these groups constitute the target audience. Teachers, for example, traditionally have had limited encouragement for sharing and collaborating, so among widely distributed educators even less incentive is present. Therefore, to create successful online communities, strong social and intellectual benefits that cannot easily be accomplished in face-to-face communication must be realized—and innovative technology must be a part of that overall package.

In corporations, knowledge management has addressed the generation, representation, organization, storage, dissemination, transformation, and protection of both tacit and explicit knowledge. Knowledge management also supports and enhances the establishment of an environment and a culture in which knowledge can be shared and can evolve.

This study explores the way in which a socio-technical infrastructure for community networks, TeacherBridge (<http://teacherbridge.cs.vt.edu>)—which embodies knowledge management as a strategy for continuous teacher development—can improve communication and collaboration among educators. As a component of our study, we investigate how knowledge-sharing environments can

support an alternative approach to traditional teacher collaboration that has been restricted by temporal and spatial limitations, as well as by individualism in teaching practices. Also, we describe the features and functionality of the TeacherBridge system and show how it can be leveraged to support the management of both tacit and explicit knowledge in online communities of educators.

In the following section, we discuss how home networking technology and knowledge management can facilitate teachers' collaboration. We also study the existent and well-known examples of online communities of educators: *Tapped In* [18] and the *Inquiry Learning Forum* [11]. Then, we describe in detail the features and characteristics of our own socio-technical infrastructure for communities of educators, TeacherBridge. Finally, we discuss the design of the TeacherBridge system with regard to activity theory [12] and minimalism [37], which are useful analytical frameworks and devices for explaining the socio-technical structure of communities and guiding the design of more easily accessible community networks.

2. Home Networking

About twenty years ago, futurist Alvin Toffler, in his book *The Third Wave* [49], envisioned the impact of new technologies on family/work life and the home of the future:

“Apart from encouraging smaller work units, apart from permitting a decentralization and de-urbanization of production, apart from altering the actual character of work, the new production system could shift literally millions of jobs out of the factories and offices into which the Second Wave swept them and right back where they came from originally: the home.”

As Toffler suggested, some aspects of our social life have been already incorporated into our homes [42]. Today, many people use the Internet to purchase airline tickets and other goods, and they play online games using a home-entertainment box. Advanced home networking provides central and/or automated control of computerized household appliances through client-server or multi-tiered server architecture (e.g., central server and distributed controllers) or through P2P (peer-to-peer) architecture (e.g., distributed services). Automated homes are linked to form a virtual community, and home automation systems such as utilities, alarms, surveillance cameras, and entertainment centers are controllable from a distant network operation center. These services are particularly important for the disabled and elderly.

As such innovations in home networking become available, our jobs are becoming a greater part of our home lives. The number of people who either work from home or take work home is increasing [46]. The integration of improved computing and new communication technologies makes it possible to bring work and school to the home in the form of telecommuting and distance learning. Essentially, the advent

of the Internet and the WWW have transformed the nature of where people work and where they teach and learn. According to a Pew Internet and American Life Project study, notable numbers of Americans say that their use of the Internet increases the amount of time that they spend working at home (e.g., ten million Internet users say that they are spending more time working at home now) [43].

Teachers are also beginning to see the value of new communication technology in their daily lives and are incorporating it into their development of everyday professional practices [44]. The kinds of tasks that tend to be individually driven, require minimal instructions and checking, need not be performed at set times, and require knowledge-based concentration and research, are ideal for being performed at home [45]. For example, writing and editing documentation, reviewing notes or specifications, proofreading, indexing and linking material, planning and designing materials, and performing project management are often cited as tasks that can easily be done from home [47]. Because these tasks are common and integral components of teachers' everyday practices, more educators are becoming interested in new communication patterns and new technologies of communication and information.

Teachers also will likely agree that there is little time during the traditional school day for their own professional development. They encounter challenges when they need to collaborate with other teachers. Despite cooperative administration and careful pre-planning, teachers cannot help confronting several organizational challenges, including conflicts and crunches in school scheduling, administration, network and computer resources, unexpected events, and assessments. As a result, teachers have experienced difficulty creating a common time slot to collaborate with one another, and have been forced to complete collaborative projects after school or at home [48]. Well-connected home networks and advanced communication technology may allow teachers to more easily finish their work at home.

In addition to having computers in their classrooms, in order to experience fully the benefits of technology in their professional development, teachers should also have a home computer. In our TeacherBridge project, it was necessary to ensure that each teacher participant possesses a home computer. During the introductory workshop for the project, we distributed laptop computers among participants. We offered a hands-on session covering network configurations, simple HTML editing, and HTML/browser rendering, as well as provided continuous training support through follow-up meetings to ensure that everyone involved became thoroughly familiar with the computers, systems, and technology.

Having the right software is as essential as having good equipment. Software that truly assists teachers' collaborative efforts to prepare and manage class coverage at home by providing a concrete language and technologies for sharing knowledge is demanded. In order to share their understanding and knowledge, teachers need to converse and interact with

other teachers synchronously as well as asynchronously. They need to better use the knowledge resources that exist through their organizations, and thus, will better facilitate teaching and learning.

As a step in this direction, we built a socio-technical infrastructure for school teachers, TeacherBridge, that allows people to share their best practices, increase the quality of their knowledge, and help each other solve problems. In the following section, we highlight various aspects of knowledge management techniques in identifying, codifying, and integrating critical knowledge in communities of practice.

3. Knowledge Management

Over the last few years, the topic of knowledge management has rapidly grown in importance among business managers and information systems practitioners. Business organizations worldwide increasingly recognize the effective use of knowledge as a key-differentiating factor and as the most important resource for potential economic success [1]. As a result, many IT companies are implementing new applications and techniques to better manage knowledge, that broad and abstract notion that has defined epistemological debates in western philosophy since the classical Greek era [6].

Two types of knowledge, explicit knowledge and tacit knowledge, can be captured by an organization for its intellectual capital. Explicit knowledge can be expressed in formal and systematic language, and therefore can be packaged and codified in the form of manuals, articles, patents, pictures, videos, audios and software. However, tacit knowledge is typically embedded in individuals and generally transmitted through face-to-face exchanges, such as learning by accompanying, watching, and helping [3]. Therefore, it is difficult to extract and represent tacit knowledge directly. Rather than attempting to do so, we should perhaps devote our attention to developing a more indirect approach for facilitating greater face-to-face interactions between community members by encouraging conversations and communications. If possible, organizations should attempt to capture and incorporate both kinds of knowledge.

Knowledge management systems are, in fact, quite common, but a truly successful one is rare. To be successful, such a system must create an environment in which people can share their best practices, increase the quality of their knowledge, and help each other solve problems. Systems that effectively capture and build intellectual capital while minimizing the burden on individuals, however, are unusual. According to a 2000 University of Pittsburgh study of 2,073 industrial practitioners and managers, (a) motivation to participate and (b) establishment and sustainability of knowledge sharing are among the top ten issues in the development of knowledge management activities in organizations [2].

While such management practices are commonplace in business, to many teachers the idea of sharing knowledge through a system is foreign. Part of the problem lies with a lack of incentives that would convince teachers to contribute knowledge to a central knowledge management system. Another dimension involves the mechanisms involved with such systems. Although more educational organizations are adopting as a vital element of their overall operations the idea of sharing knowledge, many remain unsure about how to establish and sustain this concept in practice. Because of the gap between what we need to do socially and what we can do technically, there are many problems associated with identifying knowledge and being able to access and manage it in an efficient and cost-effective manner. Human activity is highly flexible, nuanced, and contextualized, and computational entities often have considerable difficulty in handling such details and flexibility. This aforementioned gap is thus simultaneously a computer-supported cooperative work (CSCW) and a human-computer interaction (HCI) problem [7].

Currently, we lack the technical mechanisms to fully bridge the gulf between the social and the technical worlds. Furthermore, many existing interactive systems are developed without the involvement, input, or advice of trained psychologists or human factors experts, who are best equipped to forecast the way that users will respond to new or different designs [8].

Although the socio-technical gap is unlikely to disappear, it certainly can be better understood and thus more effectively handled. The challenge of such a gap creates an opportunity to refocus knowledge management systems in order to produce creative and effective ways of supporting education communities of practice.

4. Online Communities of Educators

Building communities of practice has become a major theme of educators' professional development research and practice [10]. The concept can play both catalytic and direct roles in enabling teachers to promote collaboration, increase idea creation, solve problems in time- and cost-efficient manners, and, therefore, foster social capital.

As a design process for developing TeacherBridge, last summer we conducted surveys with local teachers, specifically in Montgomery and Giles counties in Southwest Virginia. We asked questions relating to three broad categories: general demographic information, current computer and teaching practices, and attitudes and efficacy regarding collaboration and management of shared materials and "know-how." 26 surveys were returned, with an average teacher experience of fifteen years, in an average of two schools.

The survey results show that most teachers already recognize the potential benefits of communities of practice for their professional development and for sharing their expertise. For

example, regarding the question, “how frequently do you ask other teachers for help or advice about professional issues?”, teachers responded that they communicate and get help from co-workers about once per week on average. To the question, “do you use computers for finding teaching resources, material, or planning?”, teachers responded that by using the Internet, they can not only gather diverse teaching resources, materials, and plans, but they can also communicate efficiently with co-workers about work issues. To the question, “to what extent do you agree or disagree that teachers can significantly improve the quality of education through collaboration?”, they answered that they strongly agree and, moreover, they claim that they can contribute to their colleagues’ professional development by influencing their teaching strategies.

The survey results show that information and communication technology changes not only how teachers *teach*, but also how teachers *learn*. The use of innovative technology using the community model alleviates the individual teacher’s dependence on isolated, “on one’s own” attempts at professional development. By collaborating with others and working with veteran educators in the communities of practice created by such technology, a fledgling teacher can thus develop practical skills more quickly and capably.

Today, through the use of high-quality Web-based educational resources and materials, plus high-speed Internet connections, more education communities of practice are improving teacher training by creating online teacher networks. To properly recognize the implications and limitations of emerging Internet technologies on the development of communities of practice, and to understand how such communities promote effective teacher development, we studied examples of existent and well-known communities of practice for teaching professionals, Tapped In [18] and the Inquiry Learning Forum [11].

4.1 Tapped In: community of education professionals

In 1997, SRI [19] created the Teacher Professional Development Institute (Tapped In), a multi-user virtual environment for helping teachers create, shape, and participate in their own professional communities [20]. From around the world, teachers and other education professionals (e.g., librarians, professional development staff, faculty, graduate students, and researchers) visit this online community of education professionals in order to have a dialogue, exchange ideas, and learn from each other [18]. To evoke a professional atmosphere, Tapped In is designed as a metaphorical “conference center” [22]. Teachers can login by using a Java applet called *TAPestry*, which combines a clickable graphics area and a chat area into one window, as shown in Figure 1.

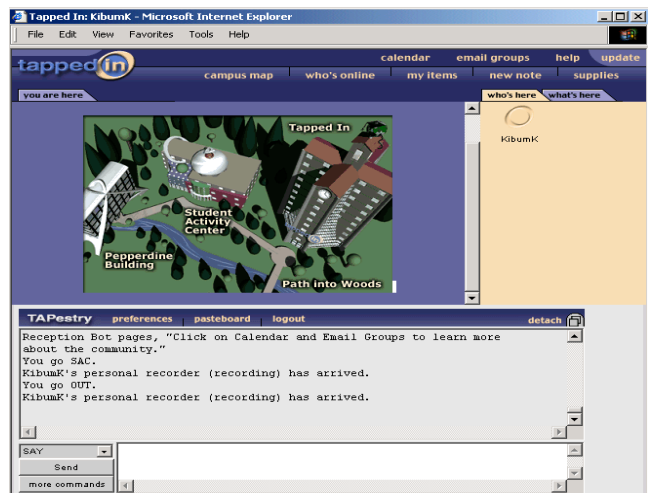


Figure 1. *TAPestry*, the user interface to Tapped In.

In Tapped In, teachers share experiences primarily through text communication, which they type into the page’s conversation window. In addition to the text window, teachers can take advantage of several other tools at their disposal [21]:

- *Whiteboards*, which work like “real world” dry-erase boards.
- *Notes*, which enable teachers to create, edit, link to their site, and share text document.
- *Bulletin boards*, which enable teachers to post and read notes for a specific group or topic.

As a socio-technical infrastructure for supporting communities of practice, in some areas Tapped In has been more successful than others. However, several issues still need to be addressed in order to more effectively meet the needs of a large and diverse educational community. For example, Tapped In lacks certain communication, database, and search tools that are necessary components of a community of practice infrastructure [40]. In the current version, collaborative synchronous creation and editing of non-text objects such as graphs, images, and charts — which we believe are also necessary components of communication in communities of practice — are not feasible.

In addition, because Tapped In doesn’t support a persistent object database scheme [40], users cannot search, retrieve, share, and collaborate on persistent data objects, such as a synchronous text editor, data tables, and charts in easy-to-use, dynamic ways. Instead, it only provides proprietary, static interfaces (i.e., as noted, current incarnations of Tapped In have focused primarily on text-based group conversations). An XML-supported database, which can represent and store persistently the state of objects in an XML format, could be one possible solution to this problem. Intelligent agents technology may also be used to augment

and possibly replace some human supports in Tapped In. For example, a software agent would capture and record a member's personalized preferences by using artificial intelligence techniques, and could assist her/him by predicting needs, recommending resources, and providing tips on necessary information for activities or conversations in which she/he has engaged. For new users, an agent could also watch their mistakes and suggest tips for error recovery [22].

4.2 Inquiry Learning Forum (ILF)

The Inquiry Learning Forum (ILF) is a Web-based professional development system designed to support a virtual community of in-service and pre-service mathematics and science teachers working together to share, improve, reflect upon, and create inquiry-based pedagogical practices [23]. Inquiry uses a dynamic approach to learning that involves not just acquiring information, but also building an increasingly rich, tacit knowledge of learning practices, as well as creating a context within which teachers can engage in these practices [23, 24]. The ILF enables educators to participate in discussions with other teachers, scientists, and educators; gather and share inquiry-based lesson plans and resources; examine videos of other teachers' classroom environments; and develop their own personalized professional development plans.

The "visiting-the-classroom" metaphor can be used to explain the design of the ILF [24]. When teachers login to the ILF, they can "visit" several virtual spaces that are typical of a school building. Having a variety of participant spaces rather than a single "classroom" is believed to promote online dialogues and collaborations. One of the main places of interest is the ILF *Classrooms*, where teachers can view videos of other teachers' actual lessons. The *Classrooms* space also includes lesson plans, reflective commentaries from teachers, links to various standards, an overview of the lesson, discussions of teaching activity, and examples of work by students. On the home screen of the ILF (see Figure 2), the *Classrooms* link is located in the lower left corner.

In addition to *Classrooms*, there are several other virtual spaces designed as vehicles for supporting the professional development of ILF teachers [23]. First, the ILF *Collaboratory* offers a place where groups or teams with similar curricular interests can share resources, ideas, and experiences. The ILF *Office* is a place where participants can find out more about upcoming ILF events, get help with technology, or make suggestions. *My Desk* is the teacher's personal portal, in which she can store bookmarks to both the ILF and external resources, leave notes in her personal journal, and see what has been happening in the ILF since the last visit. The ILF *Lounge* offers general asynchronous discussion forums focused on specific topics related to inquiry-based pedagogy. In the *Inquiry Lab*, teachers can find a collection of professional development activities they can

use for their professional development needs. Finally, the *Library* is a place where teachers can find a collection of lesson ideas and Web links suggested by teachers for teachers.

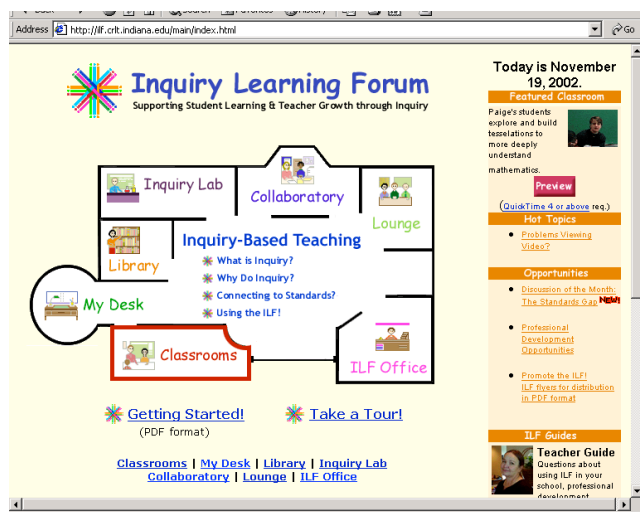


Figure 2. The ILF home screen, consisting of links to Classrooms, ILF Office, Collaboratory, My Desk, Library, Lounge and Inquiry Lab

Although, as with Tapped In, teachers interact with each other primarily through text communication, the ILF system also provides video clips as a stimulus for opening dialogue among teachers. In the *Classrooms* space, a teacher can watch a video of another teacher's lecture and then discuss the presentation with others. Although innovative multimedia technology, such as video-on-demand, might help promote collaboration, we should be cautious about adopting it wholesale. For example, in the ILF, the concept of visiting the virtual classroom through video streaming is strongly tied to a particular technology platform. To watch the video clips, teachers are required to install the latest version of QuickTime [50] software and adjust their Web browsers' preference appropriately to be able to play video clips. Since a specific commercial application and complicated client-side setup are required, less technology-savvy teachers could be discouraged from participating — a situation clearly counterproductive to the philosophy on which such communities are founded.

5. TeacherBridge: Knowledge Management in Online Communities of Educators

We are proceeding with the assumption that the formal and tacit technical resources, and the innovative and successful methods and practices in which teachers engage can emerge and be made visible through the development of interesting activities and tools involving innovative computer network technologies. We also assume that meaningful activities will arise out of our commitment to engage in participatory design

processes with teachers. We further assume that the tools will assist teachers in the preparation of their work, which involves tacit, informal, and unwritten or unarticulated rules, knowledge, and practical methods and techniques. Thus, we assume that collaboration with, or sharing of, resources can be helped by facilitating sharing and communication in communities governed by common work and purposes [32].

TeacherBridge is not just a pile of static Web pages. On the contrary, it is designed to support various teacher activities:

- *Fieldwork*: Several classes could take part in monitoring local wildlife and water quality. Data can be collectively updated in TeacherBridge’s charts and tables.
- *Online Discussion*: Chat workgroups could be set up for students to discuss any number of topics. The chat window can be integrated with a text or problem to be discussed. These chat sessions can be secured and monitored by teachers.
- *Class management*: The system enables teachers to easily publish assignments, activity guides, due dates, and the like.
- *Curriculum*: Teachers can share lesson plan ideas and collaborate on what works/what doesn’t within various contexts.
- *Go Virtual*: Additional learning strategies, such as science fairs, gardens, journals, field trips, and quizzes/tests, can be posted with TeacherBridge’s Map tool.
- *Online Portfolios*: Class projects, as well as group or individual portfolios, can be created and edited within TeacherBridge.
- *Contests*: Teachers can post students’ progress on one TeacherBridge site where all students/classes can see where they stand.
- *WebQuests*: Classes/students can organize Internet research with comments within TeacherBridge.

In order to make collaborations like the abovementioned achievable through the Web, we must break down the stereotyped conception that the Internet is best suited to passive, uni-directional, read-only media. We need to turn the Web not only into a place to interact but also into a writable medium. Currently, however, publishing Web pages can be problematic: the page must first be downloaded, then modified off-line using special HTML editor tools, and finally reposted onto the server. This annoying download-update-upload cycle makes it difficult for teachers to prepare materials and conduct activities online. Therefore, it is necessary to eliminate the notion of publishing to the Web as a separate process.

The fundamental goals of TeacherBridge are (1) to provide environments that facilitate teacher participation in knowledge sharing activities and (2) to support teachers in the finding, retrieving, and reusing of materials and activities created by colleagues. As a step in this direction, TeacherBridge makes it extremely easy for teachers to author

online a significant portion of materials: it offers an innovative way of direct editing and page creation through *WYDIWYG* (what you do is what you get).

Teachers can use either a *Web Editor* or a *Full Editor* to edit materials in TeacherBridge. With *Web Editor*, teachers merely type the text that they wish to add with the assistance of simplified shorthand—without having to learn HTML—and then just click the *Save* button. With *Full Editor*, teachers can interactively edit not only text, but also various non-text domain-specific objects. In order to use the *Full Editor*, teachers might want to install an application helper, called *Java Web Start* [4], which is a free Java download. Shown in the bottom right corner of TeacherBridge (see the ellipse in Figure 3) are links to these editors. Table 1 summarizes the contrasts between *Web Editor* and *Full Editor*.

Web Editor	Full Editor
<ul style="list-style-type: none"> • For basic editing within a browser • No extra software • Should work on any machine (old, slow, “locked-down”) • Not graphical (uses simple shorthand) • Creates basic pages with formatted text 	<ul style="list-style-type: none"> • Launches interactive editing software • Available on the Web as you work • Useful for “live” editing of content • Sharable in real time with others who are logged in • Supports uploading files and creating additional objects/tools • Provides chat capabilities • New tools in the works to support new kinds of classroom activities

Table 1. Two ways to edit materials in TeacherBridge

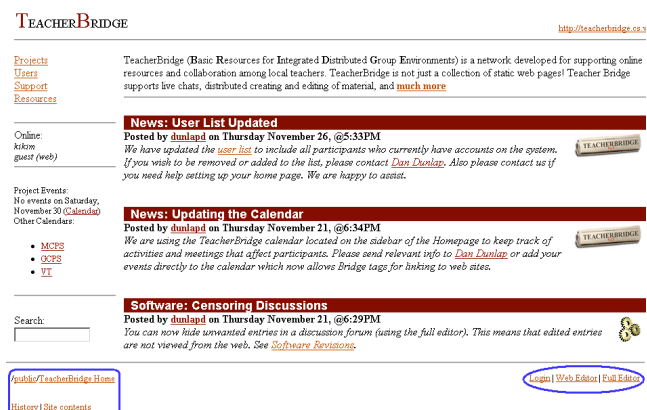


Figure 3. The Home site of TeacherBridge (<http://teacherbridge.cs.vt.edu>)

TeacherBridge is organized with a collection of sites created for a particular purpose by a particular author. Each site

contains various components (e.g., diverse Java objects including a data table, chat window, collaborative document, whiteboard, and calendar) and multiple pages. Editing and creating a Web page could be accomplished much as is possible in the *CoWeb* [33] paradigm, where simple scripting language is used to add components and pages to existing pages. This simple scripting language hides complicated HTML tags from end-users, thereby making it psychologically easier for them to create and edit. Below the editor window, helpful tips and guides for general TeacherBridge shorthand, commands, and tags are available for quick reference.

In the bottom left of the screen are a few items to help with TeacherBridge navigation (see the rounded rectangle in Figure 3). The *History* link takes a teacher to all saved versions of a page. When a teacher uses the *Web Editor*, a new version is loaded whenever she clicks the *Save* button. However, when using the *Full Editor*, a teacher must save new versions manually by going to the *File* menu and selecting “*Save Version...*” Then, the *Create Version* window pops up, and the editor can append a description or comment to the instance being saved. The *Site contents* link in the bottom-left (see Figure 3) takes a teacher to a table of contents that lists all the objects of the site as hot links.

With the *Full Editor*, teachers can create new objects such as a drawing tool, data table, chart, or sharing document (see Figure 5). To create new objects, TeacherBridge provides templates that are, in principle, re-usable models. The *Full Editor* opens an *Exploring* window. The teacher then selects the site folder from the directory to which she wishes to add an object. She chooses the object to be added and clicks the *Create* button to generate it.

Teachers also can control permissions for the created objects. There are three categories for permissions: allow reading, allow writing, and allow permissions change. For each category, teachers can select specific users by typing their PIDs in the text boxes and separating them with commas (see Figure 4).

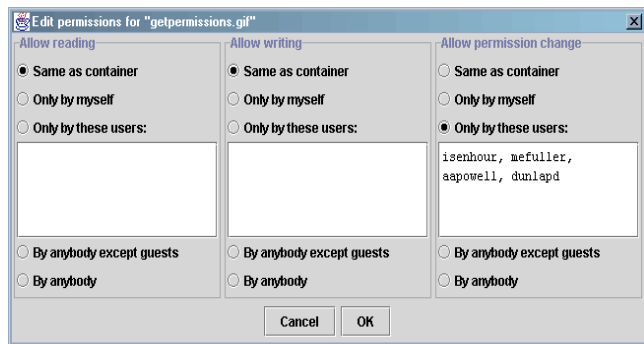


Figure 4. Teachers can control permission for their own objects using popup window.

Another useful component of TeacherBridge is the *Users* window (see the pop-up window in the upper right of Figure

5). When a teacher enters the *Full Editor*, this window pops up and shows who is using TeacherBridge via the *Full Editor* and the *Web Editor*. Teachers can open a chat session with a colleague by double clicking the PID/name on the list in the *Users* window, which opens a chat window in which messages can be typed and then sent to others. Chat sessions are saved under the *Conference* folder in the personal folder, so that a teacher can review them later at her convenience.

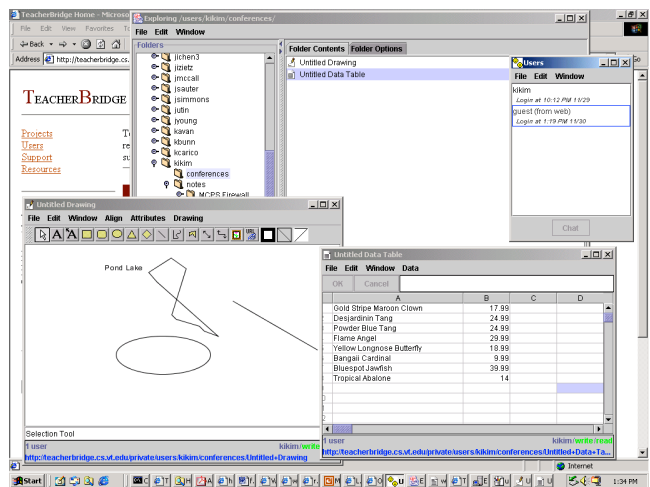


Figure 5. Full Editor mode of TeacherBridge

In addition to the above features, other useful Java components and features are allowed by TeacherBridge, such as drawing tools, data tables, charts, discussion forums, and editable equation objects. The TeacherBridge system is continuously undergoing development and actively implementing more innovative components and tools to assist teachers effectively.

6. Activity Theory and TeacherBridge

To better understand how a system such as TeacherBridge can facilitate the sharing of knowledge among widely dispersed members of a community, activity theory serves as a useful analytical framework for explaining the socio-technical structure of such communities, in essence, characterizing active relationships among community members, task artifacts, and the community of practice. Theoretically and methodologically, activity theory in HCI has addressed issues that principally involve the use of computer artifacts. Activity theory implies that human actions and interactions cannot be understood as a simple aggregation of behavioral atoms, and argues that consciousness is rooted in practical engagement with one’s society [12]. As the use of artifacts is a part of social activity, engagement is socially and culturally mediated by the community in which such activity is embedded or constituted [12,13].

As illustrated in Figure 6, Engeström’s model of an activity system’s basic structure is made up of embedded triangles

which represent the *subject-object-community* triangle of pre-human activity, as well as the components that mediate the relations of human activity with socially-constituted forms: *tools, rules* and *division of labor* [14, 15, 16].

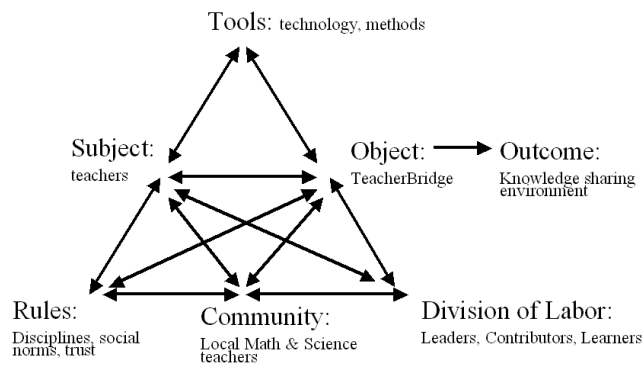


Figure 6. The diagram of an activity system structure illustrating the use of TeacherBridge

In the model, *subject* refers to the individual or sub-group whose agency is chosen as the point of view in the analysis. *Object* refers to the raw material or problem space at which the activity is directed and which is modeled or transformed into an *outcome* with the help of physical and symbolic, internal and external *tools*. Activities take place in the context of, and are influenced by, a surrounding *community*, which shares the same general *object*. *Division of labor* refers not only to the horizontal division of tasks among members of the community but also to the vertical division of power and status. Lastly, *rules* refer to the explicit and implicit regulations, norms, and conventions that constrain interactions within the activity system [17].

Last summer, as part of the participatory design, an introductory one-day workshop for TeacherBridge was held, during which the entire design team and teacher participants jointly discussed activities included in TeacherBridge and talked about scenarios of use. The sample scenario in Table 2 illustrates how activity theory could be useful in understanding the relationship among the software, social rules, and the division of labor in TeacherBridge.

Sue, a high school Math teacher, is interested in helping her students understand basic probability and statistics concepts. She launches her web browser, which opens to her TeacherBridge home page. Among other things, this page contains a list of her class project sites, with recently modified projects appearing at the top. The very top project shown is the site that she has created for her harmonic mean project. When she clicks on the top one in the list, she is taken to a page with details on the harmonic mean project, including collaborative data tables of temperatures and histograms containing the results of harmonic means for each data table.

She wants to add the complex formula that calculates a harmonic mean on her project site, and tries to figure out how to do it. She knows from discussions at the last system-wide meeting of Math teachers that classes at other schools are probably conducting similar projects for basic probability and static concepts.

When she enters the full editor mode, the Users window pops up and shows other teachers who are currently using the TeacherBridge system. Sue notices Mary, a high school Math teacher, and asks her help for creating the formula equation, using a chat tool in TeacherBridge. Mary shows Sue how to create the formula, using a collaborative equation editor in TeacherBridge.

Table 2. Teacher-driven Harmonic Mean formula creating scenario

This abovementioned scenario is a representative example of the teacher-driven scenarios. Teachers’ activity in TeacherBridge can be characterized from the activity theory perspective: For example, in this scenario, Sue (i.e., subject) uses the TeacherBridge system (i.e., object) to facilitate collaborative creation of harmonic mean formula (i.e., outcome) with other teachers (i.e., community).

In Figure 6 each of the components of Engeström’s model is labeled based on the theoretical perspective of a teacher’s activity when he or she is actively engaged in the TeacherBridge system. In this figure, teachers (i.e., *subjects*) interact with TeacherBridge (i.e., *object*), which leads to the establishment of a knowledge-sharing environment (i.e., *outcome*). The *community* includes math and science teachers in Montgomery and Giles counties. The connection of teachers with TeacherBridge is mediated by *tools, rules, and division of labor*. Various technical and conceptual *tools*, such as internal and external expertise, related literatures, available funds, and instruments support the building of TeacherBridge. In terms of *division of labor*, leaders, contributors and learners can have an effect, based on a community member’s teaching experience and familiarity with the TeacherBridge system. *Rules* — such as teaching disciplines, social norms, and trust — will be established by the community’s evolving needs. Activity theory points out that we cannot pull these components apart without violating the very essence of human activity [5]. Teachers’ activity in TeacherBridge can only be understood within the context of their interaction with the community.

7. Minimalist Technology in TeacherBridge

One of the fundamental design goals of TeacherBridge is to facilitate teacher participation in knowledge sharing activities for the building of communities of practice. According to

data collected from a survey conducted by Tapped In developers regarding what motivates and prevents people from using their system for online professional development, many teachers point out that the system's greatest drawbacks involved lack of time for online activities, difficulty learning the required commands, and difficulty learning how to navigate the site [34]. These results indicate that designers of new systems or tools for teachers must minimize the amount of effort, technological savvy, and time required by clients to use the system effectively.

We are seeking to promote goals so that teachers feel that they are immediately engaged in realistic tasks; that their interactions are creative and display problem solving and improvisation as they work with the system; that errors provide sufficient cueing to be managed and that they can lead to productive hypothesis formation and self-directed investigations; and that teachers' professional prior knowledge is accurately and effectively leveraged in the system and application designs. These goals and expectations led us to adopt minimalist theory [36, 37] as a way to analyze the characteristics of TeacherBridge design that should help to attract and grow an online community of practice.

Although originally, minimalist theory is a framework for the design of instruction, especially training materials for computer users [30], its techniques have been extended both to other computer applications, such as word processing [37] and desktop operating systems [37], as well as to other technological domains (object-oriented programming [39] and hypermedia [38]). The key ideas in the minimalist approach are to present the smallest possible obstacles to learners' efforts and to accommodate all learning strategies [36]. We illustrate here the characteristics of the TeacherBridge project from the minimalist perspective.

The minimalist approach encourages the user to select meaningful tasks on which to work. When the learning task itself is the learner's task, when the situation is under the learner's control, and when the activities of learning are personalized by that learner, participants are motivated and educational outcomes are greatly enhanced [36]. In the TeacherBridge project, each teacher participant's knowledge-sharing activity is personalized by his/her own long-term task, such as creating an electronic discussion forum for literature groups at Blacksburg Middle School (BMS) and Virginia Tech (VT), and Pandapas pond and Poverty creek field data monitoring. Those real tasks have motivated teachers to participate in the design of TeacherBridge because the activities that are undertaken are directly in the service of a meaningful goal for each teacher.

In TeacherBridge, several templates are available to make it easier for teachers to start building their own projects as quickly as possible. Generally, templates in TeacherBridge are folders that include any number of objects with preformatted navigation, links, and sidebars, all of which are readily editable. This approach allows teachers to get started on projects as quickly as possible, a behavior which minimalist theory explicitly encourages: people can easily

learn by doing with concrete examples, not by being told how to do things [31, 36, 41].

Many cognitive theorists and educational psychologists have concluded that error can play an important and productive role in learning and intellectual development [28, 29, 35]. The pervasiveness of error in learning makes it unrealistic to imagine that user mistakes can be eliminated [36]. One of the main activities in the design of the minimalist approach is compiling an inventory of user errors, particularly those that are typical or have serious consequences [36]. To support error recognition and recovery, TeacherBridge maintains a *Feedback* site at which teachers can describe and discuss problems and errors. At the same site, developers can post how feedback has been addressed. Teachers figure out their problems by referring to the Feedback site. The other useful widget for error recovery is *History* (see Figure 3), which saves all previous versions changed by users, thereby providing support for teachers to recover the original state of a version and manage errors.

In the minimalist approach, one of the most important aspects of designing new systems is to understand users' prior knowledge and motivations, and then find productive ways to exploit them [36]. Using a common ground approach is one possible technique for accomplishing this goal [9]. For example, in TeacherBridge, the Web browser metaphor is effectively employed in designing the user interface for *Web editor* and the desktop directory metaphor for *Full Editor*. Teachers' common prior knowledge is accurately and efficiently leveraged in the TeacherBridge system.

To create practical solutions, any system needs to experience and exploit the fine details of real situations [25, 26, 27]. During TeacherBridge's project development, we focused on creating a detailed description and recognizing representative activities in teachers' work practices and in their beliefs about knowledge sharing and peer collaborations. We conducted an ethnographic study of the local education community of practice that began with semi-structured interviews with each teacher about current teaching practices and situations. We then conducted face-to-face meetings with administrators from Montgomery and Giles county public schools in Southwest Virginia concerning their staff development priorities. During a large number of meetings and email correspondences, we focused on identifying how teachers currently keep track of resources, materials, plans and activities; how teachers may share, reuse, and adapt materials (i.e., how they manage teaching knowledge); and how a socio-technical infrastructure can support active teaching communities. By engaging in long-term participatory design, we can help teachers learn new tools and refine them to be more appropriate.

Table 3 summarizes the consequences of adopting the minimalist approach as design features for making the system easier to learn and to use.

Minimalist approach as design features	
<i>Minimalism</i>	<i>Design features</i>
• Working on real tasks	⇒ Meaningful tasks for each teacher
• Getting started quickly	⇒ Making templates available
• Reasoning and improvising	⇒ Providing discussion spaces
• Reading in any order	⇒ Organizing small units and providing search functionality.
• Coordinating system and training	⇒ Creating tutorial under full systems
• Supporting error recognition and recovery	⇒ Providing history and feedback
• Exploiting prior knowledge	⇒ Common ground metaphor interface
• Using the situations	⇒ Participatory design

Table 3. Minimalist approach as design features to generate system easier to learn and to use.

8. Discussion

Innovative anyone/anywhere information technology has led to substantial changes in numerous aspects of our everyday lives. Ubiquitous access to the Internet makes it possible to break down barriers of time and space, so that many people can work at home, communicate with co-workers after office hours, and hold virtual meetings remotely. In doing so, new communication patterns have been created, and growing virtual communities have become a global phenomenon.

However, building a networked community is not as simple as merely connecting computers. In fact, the growth of our Internet-oriented society raises many research issues. First and foremost, we must recognize the implications and limitations of emerging Internet technologies on the fostering of communities of network, as well as understand the role of these technologies in promoting social capital, civic engagement and a sense of community.

In our design of TeacherBridge, we have focused on how a socio-technical infrastructure can support and re-shape the process of knowledge sharing and organizational learning in education communities of practice. Based on innovative computer network technologies, the system can facilitate teachers' involvement in knowledge-sharing activities and in management of professional resources at home as well as at the office.

The TeacherBridge system is still currently undergoing development, and we are actively expanding, diversifying, and testing the system with local communities of practice. While this preliminary version of TeacherBridge has focused on local science and mathematics teachers in two Southwest Virginia counties, we hope that the resources and methodology developed can be applied to a wide variety of

similar situations, such as the networked home office or small office.

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