Carroll, J. M., Rosson, M. B., Dunlap, D., & Isenhour, P. (2005). Frameworks for Sharing Teaching Practices. *Educational Technology & Society*, 8 (3), 162-175.

Frameworks for Sharing Teaching Practices

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ABSTRACT

In many organizations, collaborating with peers, sharing resources, and codifying know-how are not typical facets of work activity. For such organizations, knowledge management support must help people identify and orient to opportunities for collaboration and sharing, articulate values and best practices, and assimilate sharing knowledge as an everyday experience. We discuss a participatory design project in which we are exploring these issues in the design of knowledge management support for public school teachers, leveraging a community networking infrastructure and everyday representational frameworks for knowledge.

Keywords

Knowledge management, Teacher professional development, Visualization

Introduction

Organizations learn and have knowledge. The knowledge is dispersed among the people in the organization. Some is codified in documents and policies, some is embodied in projects and results, and some is tacitly held by individuals or small groups. The challenge of *knowledge management* in organizations is to ensure that organizations continually learn, that new knowledge is effectively incorporated into work practices, and that the knowledge is accessible when needed (Choo, 2000.). This is not easy to achieve in any organization. People want to teach and learn, to understand and share, but their jobs have traditionally been designed for productive action — learning and sharing are often luxuries that occur outside normal routine.

We are investigating knowledge-sharing practices among public school teachers. Schools provide a valuable and difficult organizational context for understanding and enhancing knowledge management. Traditionally, teachers collaborate very little; they manage their own resources and enjoy great discretion in their pedagogical practices (Briscoe & Peters, 1997; Schlager & Fusco, 2004; Tyack & Cuban, 1995).

This culture of autonomy has come under pressure through the past decade. Contemporary learning theories identify collaboration among students and teachers as a key enabler of better educational outcomes (McGilly, 1994; Shachar & Shmuelevitz, 1997). And systemic reform in education has increased uniformity in learning objectives and assessment (National Research Council, 1995). Thus, at least to an extent, there is converging motivation on the part of teachers, administrators, and government overseers to enhance knowledge-sharing practices in schools.

This transformation in knowledge management for teachers is conceived of as teacher professional development, a long-standing category of activity and programs in school systems. In this view, knowledge management is tantamount to greater emphasis on teacher initiative in designing and implementing professional development programs.

Our approach involves (1) a commitment to long-term participatory design (Carroll, Chin, Rosson, Neale, Dunlap & Isenhour, 2002) and (2) assimilation of knowledge management tools and resources into the existing community computing infrastructure, the World-Wide Web (Isenhour, Rosson & Carroll, 2001; Ganoe, Somervell, Neale, Isenhour, Carroll, Rosson & McCrickard, 2003).

Knowledge sharing in schools

Since 2001, we have worked with a group of teachers in two rural school divisions in southwestern Virginia, USA (Montgomery and Giles County Public Schools) to understand their knowledge-sharing practices, to identify problems, needs, and opportunities in their professional context and work culture, to explore possibilities for enhancing knowledge sharing through new procedures, tools, and content resources, and to assess the efficacy of interventions with respect to personal, social, and organizational goals. We summarize our initial requirements analysis of knowledge management in schools, and then describe four different frameworks for representing and accessing teaching knowledge.

As a starting point, we analyzed ways in which the organizational context of schools influences knowledge sharing, including societal attitudes towards teaching and education, and towards teachers and schools, changes in conceptions of learning and education—particularly new emphases on collaboration—and systemic reform and standardized testing initiatives (especially, in our case, the Virginia Standards of Learning, 1998). A complete report of this analysis can be found in (Carroll, Choo, Dunlap, Isenhour, Kerr, MacLean & Rosson, 2003).

Our analysis identified three levels of knowledge sharing, each representing a broad category of objects that teachers could potentially share (see Table 1). The three levels differ with respect to the difficulty of making contributions to the base of shared knowledge, the effort required to evaluate the potential for use of shared objects in new classroom contexts, and the effort required to actually adapt and use shared artifacts. This analysis was derived from a long-term participatory design project with six high school and middle school science teachers; in which we developed and studied the deployment of a Virtual School for collaborative, project-based learning (Carroll et al., 2002; Isenhour, Carroll, Neale, Rosson & Dunlap, 2000). The levels also comprise a hypothesis about scaffolding "transitional systems" in the sense of Papert (1980; after Piaget & Inhelder, 1969). That is, the three levels represent an implicit progression in *degree* of knowledge sharing. They characterize a possible adoption process, and provide an initial framework for a "language" of teacher professional practice. (These ideas are developed further in Carroll et al., 2003).

At the lowest level, teachers can exchange tangible resources. The six teachers in the Virtual School project, for example, shared pointers to interesting web sites, laboratory equipment, construction kits, and other physical artifacts. A professional development workshop for teachers might produce a list of such resources that participants might seek to share in their work.

Technology to support sharing at this level could include tools for tracking inventories and handling reservation of physical artifacts, maintaining lists of virtual artifacts, and discussing problems with or tips for using the shared resources. Contributing to a shared base of knowledge about such resources may require relatively little effort, and the resources may be usable for a variety of classroom activities. The effort required to evaluate the potential usefulness of, for example, a given piece of lab equipment, and then design a useful activity based on the equipment in the context of a particular classroom may, however, be a daunting task.

At the next level, we observed that teachers share designs of classroom activities in the form of lesson plans, objectives, and grading policies. In some sense this was a natural outcome of the Virtual School project because of the emphasis on planning and coordination of cross-classroom collaborative activities. The teachers developed and shared variations on existing lesson plans and teaching objectives, as well as developing entirely new activities; they also shared their schemes for grading class projects as part of developing commensurate grading policies across collaborating classes. Beyond our prior work with the Virtual School project there are many other web-based and offline teacher development projects that generate collections of lesson plans.

Table 1. Levels of knowledge sharing among teachers

Sharing Level	Examples from Virtual School project
Tangible resources	Pointers to web sites, Lego construction kits, lab equipment
Plans and objectives	Lesson plans for labs, worksheet templates for peer mentoring activities, grading policies
Prototypes	On-line lab reports, web sites with project summaries and photos

Possible technology support for sharing plans and objectives includes tools for authoring, discussing, annotating, and refining plans, activity materials, and grading policies. Compared to items in a list of shared resources, such elements of an activity design will be inherently more specific to the context of the authoring teacher's classroom. Development and articulation of plans and objectives are also likely to be more difficult tasks than contribution to a knowledge base of available resources. It is, however, also likely that a successful activity or practice captured in the form of a plan will be more easily adaptable and reusable in other classroom contexts, since relevant elements of the plan can simply be copied, modified, and added to the knowledge base.

The third level is sharing of "prototypes." These are artifacts produced by students or summaries of student work for a given activity, and may be thought of as implementations of designs (plans and objectives) that could be shared in the second level. In the Virtual School project, the teachers could access in-progress and completed student work both from their own classes and from the classes of teachers with whom they were collaborating. Numerous other examples of publication of student projects can be found on the web, usually representing isolated efforts by individual teachers. For example, another teacher in the local school system has created a detailed web site with data collected as part of an extended stream monitoring activity.

Technology to support sharing at this level might include tools for authoring and accessing completed or in-progress student work (e.g., completed worksheets or quizzes, photos of projects, data sheets, or summaries of collected data), as well as tools for extracting templates from, discussing, and annotating posted artifacts. The effort required to make prototypes available for sharing may be largely mechanical, since students would do most of the work of actually creating the data. Ideally, technology aimed at supporting this type of sharing would simplify summarization and publishing tasks that teachers already include as part of classroom activities.

Prototypes shared in this way are iterative and ongoing, allowing teachers to collaboratively critique, scaffold, and adapt new materials as teaching needs and opportunities evolve. This increases the likelihood that both tacit and explicit knowledge surrounding these exercises will be shared. Teachers who develop and share locally enacted materials are able to contact, question, and engage relevant teachers, and this helps to articulate, produce, and reuse one another's professional knowledge. This type of knowledge building is strengthened by shared region, shared particular local problems, common interests, and common concerns faced by teachers in similar situations and environments.

As instances of situated classroom know-how, prototypes are unique to a particular activity performed by a specific group of students, but templates of underlying artifacts are reusable, data can be incorporated into future activities, and teachers can make independent assessments of the design of the activity. Refinements that allow useful activities to be incorporated into new classroom contexts may therefore be easier to identify. The success of tools such as CoWeb (Guzdial, Rick & Kehoe, 2001) in supporting activities that evolve over time and across disciplines demonstrates this potential.

The three levels of knowledge sharing among teachers, the three types of sharable objects, illustrate the three key properties of discretionary knowledge management. Teachers affiliate when doing so addresses shared concerns, but they do not have a culture of collaboration (Tyack & Cuban, 1995). Sharing concrete resources, lesson plans and activities, and situated classroom know-how is immediately rewarding. It does not require a culture of collaboration, but it can help to foster one.

Bilateral mutual exchanges, or sharing within small peer groups, addresses the standing mission of teachers and schools while still allowing any given teacher to participate in his or her own way. There are no organizational protocols for goal management in public schools. Indeed, the dialogs of knowledge sharing among teachers are as diverse as the teachers, and largely invisible to school administrators.

Finally, the exchange of concrete resources, lesson plans and activities, and situated classroom know-how is carried out informally. There is no clearinghouse of technical common ground. Teachers have substantial, and often unique knowledge about where they might find a certain chemical or specimen, which colleague tried a given activity with surface tension or the psychophysics of taste, and who might know how to pose rewarding questions about the motion of slinkies or fix a model train.

We are trying to encourage knowledge sharing innovation by codifying a design space of visual frameworks for capturing, storing, accessing, and sharing teachers' professional practices. Our goal is to make vivid to ourselves and to the teachers how the three kinds of objects identified in our requirements analysis can be shared, and indeed how the teachers imagine anything can be shared. This is itself a wide-ranging endeavor involving scenarios for (a) authoring (in the sense of codifying) content, (b) posting descriptions of resources, lesson plans and activities, and classroom implementations, (c) refactoring contributions to make them more attractive, accessible, and reusable, (d) searching and browsing posted content, (e) adopting, adapting, specializing, and integrating resources, plans, and implementations, and (f) evaluating shared materials — possibly among other scenarios.

In the balance of this paper, we focus on (d) searching and browsing posted content. In the interests of space, we focus only on first-order issues; for example, we do not consider the complexities of what objects might be retrieved with what other objects.

Visualizing knowledge for reuse

As part of our exploratory design process, we have developed several different concepts for organizing and presenting teachers' professional knowledge. The central requirement in developing these concepts has been to identify and leverage teachers' everyday knowledge about their own activities: if the teacher-participants are unable to understand or identify with the design space, they will similarly be unable to internalize it and apply it in their own design envisionment process.

We hypothesize that teachers will view knowledge management from an informal perspective, one that hinges on personal relationships with other teachers as well as a somewhat ambiguous and flexible notion of what, how, and why concepts and ideas are shared. Furthermore, we hypothesize that content that they choose to share will vary widely from concrete artifacts to open-ended and socially-mediated work practices.

These concerns and expectations have led to four different proposals for organizing and visualizing knowledge, coupled with a general instance-based mechanism for retrieving pieces of knowledge. The proposals for knowledge organization leverage the everyday rubrics of *place*, *time*, *social relations*, and *usage*. We propose that these rubrics are fundamental to how people organize their personal experiences. One's familiar places, times, social interactions, and work practices evoke community attachment and community engagement. At the same time, we argue that these dimensions support some of the special concerns of discretionary knowledge management as defined earlier.

Our design vision combines these dimensions of knowledge organization with an instance-based knowledge exploration and retrieval technique that adapts Williams' seminal work on retrieval-by-reformulation (Williams, 1984). In all cases, one of the four rubrics provides an organizing structure for stored knowledge; the retrieval mechanism then operates on this structure as a sort of filter, where the user successively edits the attributes of a knowledge base instance to select or remove knowledge base candidates from the interactive visualization (Carroll, Herder & Sawtelle, 1987).

We expect that the retrieval-by-reformulation paradigm will be particularly useful in this knowledge domain where the goals will often be vague and thus could be addressed by many possible results (e.g., a search for advice on forming small groups for class activities). The general mechanism is founded on theories of human memory positing that people think about categories of things not in terms of formal attributes, but rather in terms of examples (Norman & Bobrow, 1979). Offering a candidate instance as an editable query addresses this tendency to think in terms of examples, while simultaneously enabling the dynamic exploration of an ill-structured knowledge base.

We illustrate a possible realization of our project through a scenario annotated with example displays. In the scenario (shown in italics in the following subsections), a teacher is planning a class activity in environmental science. She wants to make use of a local pond that she can "visit" in a place-based community computing infrastructure. At the pond site, a variety of resources have been posted by other teachers. She reviews these using an assortment of tools and representations to help her clarify what she wants to do and what and who can help her.

Place-Based Knowledge

Physical materials, apparatus, and equipment, as well as plans, activities, and situations are, or will be, located at specific *places*. Zoological and botanical specimens from southwestern Virginia are located at the Natural History Museum; books for a project on black holes and public access to the Internet are located at the Montgomery-Floyd Regional Library; rezoning proposals and the current master plan for Blacksburg are at Town Hall; data and apparatus from usability experiments are located at the Center for Human-Computer Interaction; and so forth. We propose that locations can serve as a vivid index into shareable content (Hester, 1993).

Our design vision for teachers' knowledge management is illustrated with examples from the TeacherBridge project—a community network (Kim, Isenhour, Carroll & Rosson, 2003; Carroll & Farooq, 2005). TeacherBridge is an authoring environment that teachers can use to build websites and other online resources for their class activities (http://teacherbridge.cs.vt.edu). The teachers' authoring tools are drawn from Bridgetools, a Java-based collaborative architecture for building synchronous and asynchronous applications (http://bridgetools.sourceforge.org). Bridgetools supports wiki-style editing of web pages in place as well as a full-featured interactive environment for creating, editing, and composing components such as maps, calendars, data tables, freeform drawings and images, and discussion boards. Figure 1 illustrates a hypothetical teacher working with some of these tools as part of the Pandapas Pond project, a shared website built by a collection of science teachers in rural southwest Virginia.

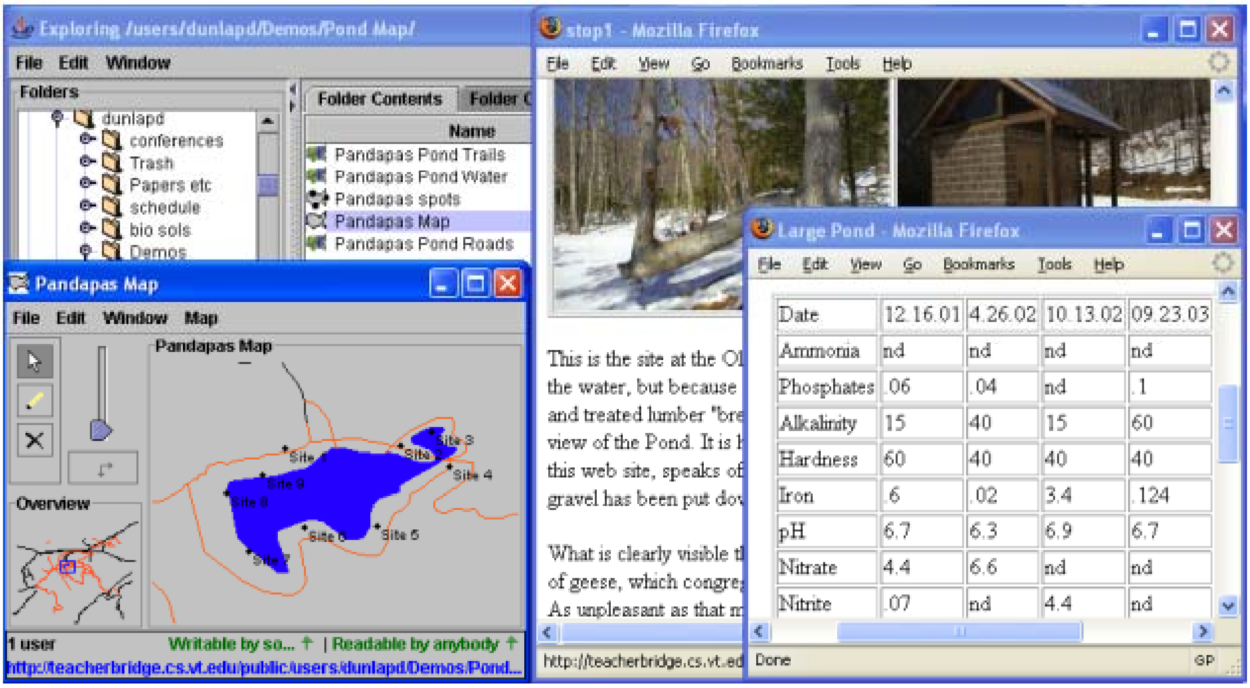

Figure 1. Working on the Pandapas Pond site in TeacherBridge

Bridgetools provides an interface to a persistent object database; one attribute an object can maintain is its current spatial location (Isenhour et al., 2001). In our design vision, concrete resources (e.g., the map of the pond and the water quality report in Figure 1) would be associated with a specific physical site, namely the location of Pandapas Pond in the real world. In the map tool shown in Figure 1, the small overview in the lower left corner can be panned to change the portion of the map seen in the larger view (the small rectangle in the overview indicates what is currently in view); the user can control the resolution of the map using the zoom controls in the upper left. Teachers might interact with an online map of this sort to find and visit online projects like Pandapas Pond, leveraging their existing knowledge of the town and region.

By default, a TeacherBridge map would display any places defined by users. In some cases this may be quite appropriate, for example when a teacher has no specific goals but is simply browsing the system for interesting information. When the retrieval goal is more specific, the map display could be filtered using the retrieval by reformulation mechanism described earlier. For example, a teacher might enter the keywords "ecology" and "exhibits". The result would be a randomly selected ecology exhibit object, as well as a custom TeacherBridge map that displays the place holding this exhibit, along with any other places that hold similar artifacts. At this point, the teacher could refine her query or browse the places on the map.

Maps are familiar representations of places. Maps remind viewers of people and resources located within the mapped place. A map evokes memories of interactions and activities that occurred at various locations. TeacherBridge's interactive map depicts the area in which the teachers live and work. Teachers can use the map to locate shared resources, and communicate with peers about the shared resources (the environment enables real-time chats and discussion boards to be associated with objects). Such technology enables informal knowledge management dialogs that are tied to teachers' place-based professional knowledge and experiences.

An important feature in this regard is the integration of traditional classroom resources such as datasets , graphs, and images with social resources such as pedagogical tips, questions and answers, or teaching observations.

The interactive map should help teachers to identify and act on opportunities for collaboration. By depicting the places where interactions and joint activities have occurred in the past, it suggests that partnerships and reciprocal dependencies might be effective and pleasant. The communication tools in TeacherBridge enable dialogs that can articulate and discuss goals, manage progress, and assess achievement. Supporting such discussion in a private teacher-teacher space, and using a relatively "lean" communication medium (e.g., text chat), should increase teachers' comfort and willingness to address ambiguous or sensitive issues of teaching practice and school policy (Shachar & Shmuelevitz, 1997). Finally, the mapped place in TeacherBridge literally is the community. It exploits people's everyday experience to create and emphasize community common ground, serving as a foundation for domain-specific technical common ground.

Sharon is a science teacher at Blacksburg Middle School. Next week she will begin to organize her seventh graders for the annual science fair. In the past she has found that many students get a slow start because they are unable to come up with a project that is both interesting and doable, so this weekend she plans to spend some time researching a few topic areas that she can offer as starting points.

Sharon believes strongly in the recent education trend toward authentic learning, and she thinks she can add authenticity to the kids' projects if they are related to local issues. She remembers some discussions in the New River Valley Current over the past few months about pollution concerns at Pandapas Pond, so she figures this might be the source of some good topics. Before driving out to look for project sites, she decides to check out this location in the TeacherBridge environment.

When she starts up TeacherBridge, she finds herself in her usual spot — her class' online website — so she pulls up a map of the area to locate and move to Pandapas Pond. When she double clicks on the pond project, she recognizes several views from around the pond and guesses from these images that the marsh section north of the pedestrian bridge must have been attracting some attention recently. As she looks more closely, it seems that this area may be filling up with weeds and mud; what used to be a sandy area is now partially covered with sludge. She sees that there are a few recent discussion posts from some colleagues at Christiansburg Middle, and a link to several data tables. Maybe these projects will convey some issues or methods that she can adapt for her own students.

Use-Based Knowledge

In a business organization, standard operating procedures comprise a useful rubric for organizing knowledge. They remind members that the knowledge has been used, and illustrate how it can be used. In a less formal organization, like a middle school faculty or a residential community, there are often no standard procedures, but there are folkways regarding "the things we do" and "the way we do things" (Bellah, Madsen, Sullivan, Swindler & Tipton, 1986). These concepts are vague, tacit, and frequently flouted, but they can be resources particularly for new members. In teaching communities, such knowledge is often articulated as best practices, and may be shared informally through teacher-to-teacher interaction or more formally through planned workshops.

Sharable objects — material resources, plans and designs, and implemented activities — have usage histories that provide an aggregate recommendation as to their future use. For example, a particular simulation of the Bernoulli effect (relating the velocity and pressure of a fluid) might have been created as a student project, shared online by the student's teacher, and accessed more than any other piece of simulation software. Such information would be useful to a teacher looking for such a classroom resource.

TeacherBridge projects are composed of individual objects like web pages, calendars, data charts and so on. Each of these objects can maintain a history of its own use: who created it and when, who opened it, who changed it, and so on. Each object can also be browsed within the TeacherBridge project folders, and objects of interest can be copied and used as-is, or they can be modified to suit slightly different needs. Thus one particularly important form of usage in the environment is *reuse*, wherein one educator chooses to develop a new object or activity based on an existing one. In some cases this is as simple as duplicating an object and moving it to a new project folder. In other cases the editing required will be more substantial and may require assistance from the original author or other knowledgeable colleagues. Figure 2 illustrates one such example, a discussion MOO (a spatially-organized persistent chat) that was created by one teacher in consultation with the research team, and a second MOO that was created by another teacher with guidance from the first.

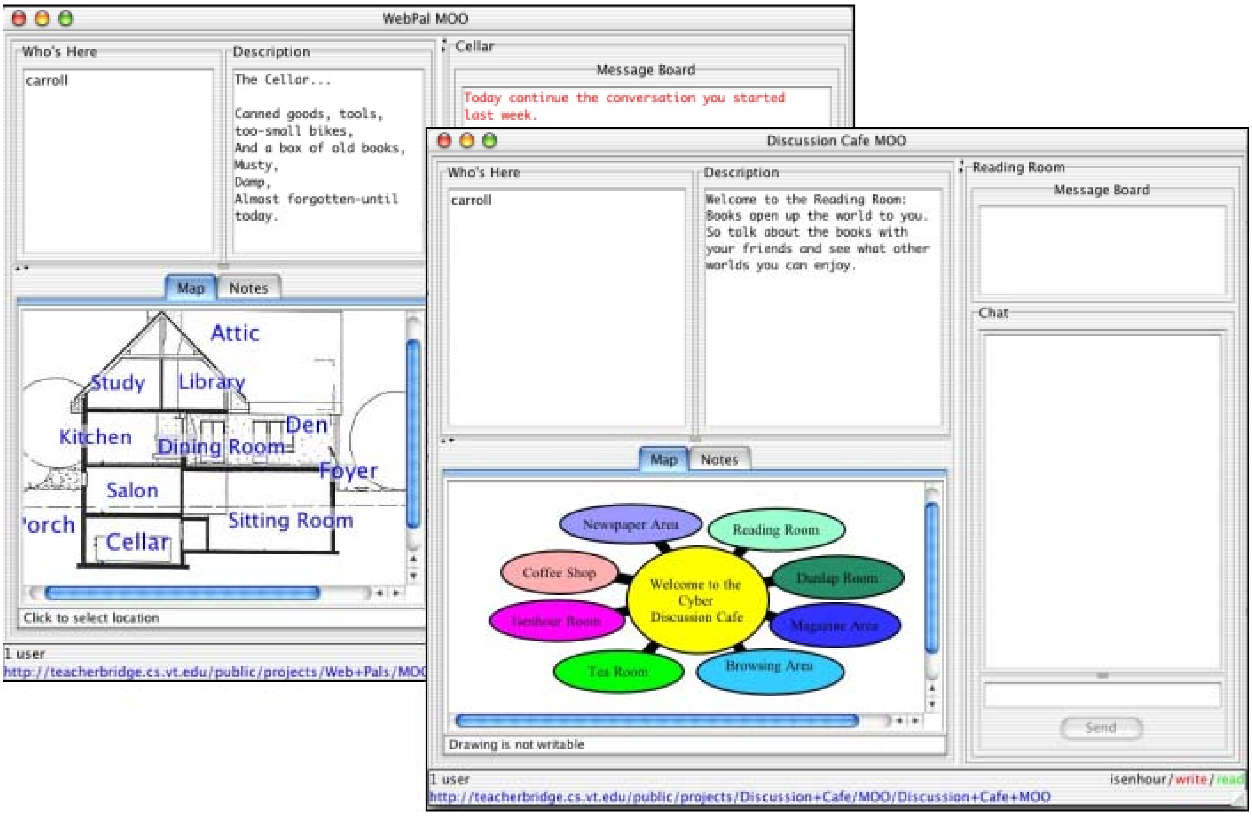

Figure 2. An example of reuse within TeacherBridge: a discussion MOO object was developed by one teacher and later adapted with her help for use by another

Another example of use-oriented knowledge is offered by the concept of shared data "wear" developed by Hill, Hollan, Wroblewski, and McCandless (1992). These researchers described how the scroll bar used to navigate a document might be darkened at each point in proportion to the number of edit or read accesses of the corresponding data record. The resulting scroll bar would display the varying extent of "wear" throughout the document. This idea has been adapted widely. For example, the Footprints system tracks and visualizes various aspects of user activity in a Web site as a navigation aid (Wexelblat & Maes, 1999). Its annotation tool displays what percentage of users that have chosen each link on the currently viewed page.

Patterns of "wear" on data records and links profile and reify typical behavior, making it a social resource, something members can talk about and reflect upon. Within a user community, well-worn resources may become part of the community's common ground, and use of these resources may become folkways. Thus, use-based visualizations of knowledge can facilitate the development of knowledge sharing practices.

TeacherBridge might represent "wear" in several different ways. For example, a user might be able to open a history view of an object like the Pandapas Pond web site that shows (a) how often people have looked at it, (b) how often people have used it in other projects, and (c) how often people have adapted or specialized it. A teacher who has not yet reused any content from TeacherBridge might begin by seeing what objects other people are looking at (a), and then to focus on objects that have a history of successful adaptation (b).

At first glance, all of the projects look the same, though Sharon guesses that the ones near the image of the foot bridge are probably related to the build-up of the sludge, the ones near the larger pond image to general water quality, and so on. Rather than exploring each one in turn, Sharon first requests the "Object Usage" tool to see which projects have provoked the most interest among other visitors to this site. The links are updated to include a brief summary of visits, copies, and adaptations. Two of the links near the bridge image have the most visits, so Sharon figures that these projects may be the ones that touch on the most interesting and/or current issues. Of the two beach projects, one shows 10 downloads while the other shows 6, so she decides to start with the former.

Time-Based Knowledge

Just as every entity or event is associated with one or more places, people's resources, plans, and know-how are also associated with specific *times.* A resource is ordered, acquired, used, repaired, and replaced at points in time. An objective is identified or achieved, a plan is launched, and checkpoints within a plan are attained at various times. If a plan or objective is adapted and reused, it may be associated with multiple times that refer to both the original event and its subsequent reuse.

Time can be a very pertinent rubric for organizing sharable objects. Suppose a water chemistry activity is originally codified at a point in time. Subsequently, notes are developed regarding its support for certain Virginia Standards of Learning (Virginia SOLs, 1998). Even later, the original activity may be revised by its author to better support the SOLs, or perhaps enhanced by another teacher to incorporate recent work in biochemistry. Ordinal timing relationships like this are visualized naturally in a timeline. Because a timeline would also emphasize the "age" of a resource, it might prompt maintenance goals, for example updating a lesson plan that is ten years old.

Figure 3 is a screenshot from another Bridgetools project—a Classroom Bridge project workspace (Ganoe et al., 2003). The Classroom Bridge project was studying techniques for improving the awareness of teachers and students about the state and progress of science projects that were underway. The science experiments were carried out by groups of students distributed across two classrooms (eighth and sixth graders), over a period of several months. Two key features of the workspace were a timeline that visualized initial creation and revision of all project documents as well as teacher-created deadlines, and a concept map that students used to plan, hierarchically decompose, and initiate project activities. The timeline and concept map serve as two different indices into the same project document set, but whereas the concept map emphasizes relations among project parts, the timeline emphasizes the team's work history and important dates.

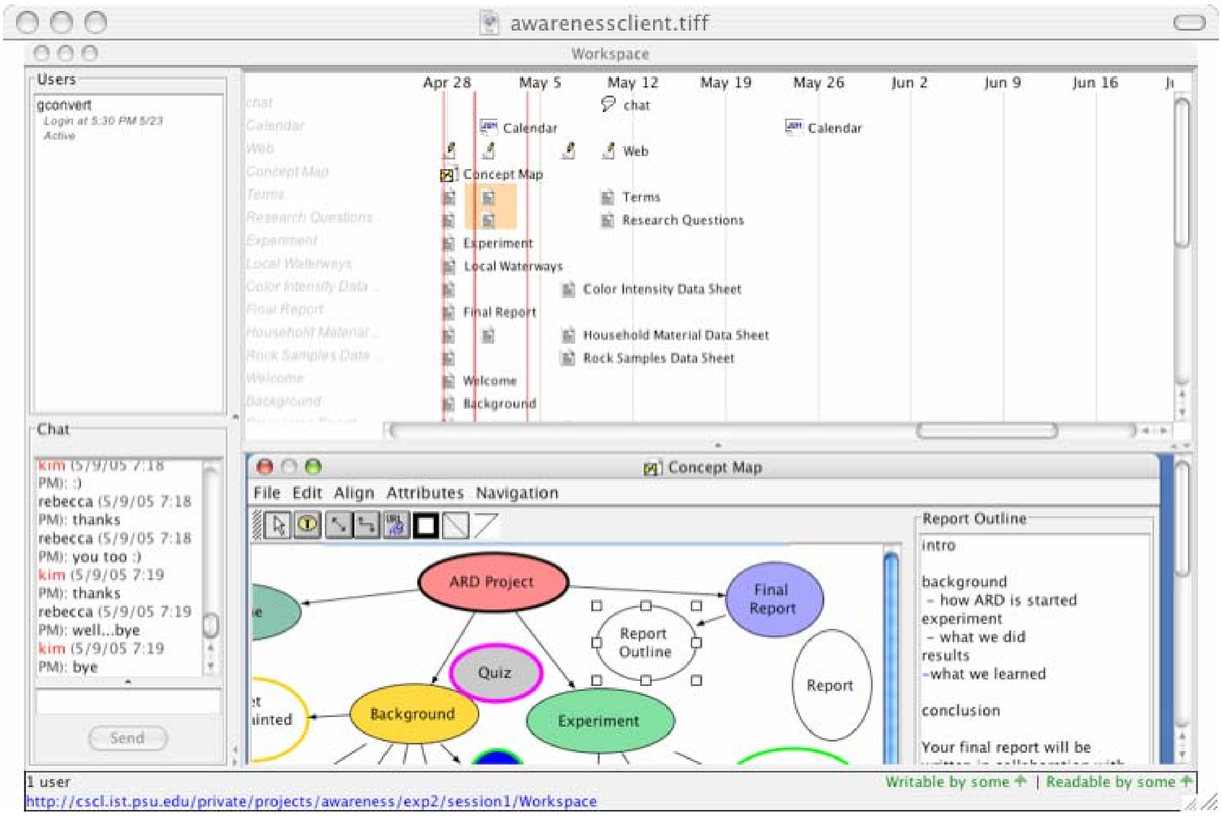

Figure 3. Classroom Bridge workspace: timeline (top) and concept map (middle) are views of the same document set; the workspace also includes a list of team members logged on and a persistent chat (left). (Ganoe et al., 2003)

A similar timeline view could be used to visualize and access the shared knowledge of teachers, although the concepts of deadlines are clearly less relevant in this case. For instance, we might adapt the example in Figure 3 such that the horizontal bars are shared projects like Pandapas Pond and the entries along the timeline indicate how recently and frequently different teachers have been contributing to the shared site. In other words, as an alterenative to scanning or zooming a map as illustrated in Figure 1, teachers might browse a timeline that lists shared projects and their components across time, filtering it as desired to simplify or focus their exploration.

Like maps, timelines are familiar representations of personal experience and activity. A timeline can have an episodic reminding function, evoking memories of interactions and activities, the order in which they occurred, their recency or remoteness to the present, their proximity in time to other interactions and experiences, and so on. We see the timeline as a personal index into time for individual teachers and for the group. Milestones in the community's history (e.g., the beginning of a school year, the date of a textbook selection) might take on a privileged status in the timeline, acting as a sort of landmark for estimating the temporal position of other relevant information. The different perceptual characteristics of varying resources (e.g., an outline lesson plan, a digital photograph, email) should also aid in the selection process.

When Sharon opens the Pandapas Pond activity, she discovers that it is a series of related small experiments that have been conducted by a variety of different teachers. She is impressed with its level of sophistication. She sees that the original project author is Joe Whistler, an environment science teacher from Giles High School; his acknowledgements indicate help from Sue Gable at Christiansburg Middle and Ben Stark, also at Giles High School. Curious, she wonders how the project ended up in its current form. She activates the "Timeline" tool, and a history view of this object is visualized off to the side as a timeline. She sees that the original idea was posted about six months ago (March 2004), and she recalls that was about the time she first saw letters to the editor on this topic. In May Joe seems to have posted some annotations related to his students' data collection, including pointers to another related project he discovered in Michigan. Later in the summer the experiments were expanded by Sue Gable, along with an annotation explaining the goal of the new measures. Finally, Joe posted a third version, including an annotation indicating that he had worked with Ben and Sue to refine the water testing methods. Sharon is impressed with the sophisticated charts and tables. This reminds her that she needs to give her class some extra homework using the charting functions in Excel. She continues on to explore more projects at the pond.

Person-Based Knowledge

Teachers themselves are resources for one another. They work together to coordinate curricula within and between grade levels and subjects. They mentor new teachers, and advise one another collegially on a variety of ad hoc problems. And more broadly, people throughout a school's local community are resources for teachers. For example, a person whose hobby is bridges can bring to life an 8th grade science class on forces. But even though parents and other residents are stakeholders in the school organization, they have traditionally not had an active role in educational activities. Exceptions are the small set of activities coordinated through parent-teacher associations, or that are public events like science fairs.

The person(s) associated with a particular aspect of teaching knowledge may impact the search, analysis, or adaptation of the shared resources in several ways. For instance, the author of an educational resource may already be known to a peer who is browsing for possibilities, creating an intrinsic interest in the resources contributed by that individual. This may interact with areas of expertise, for example a high school physics teacher who becomes a general resource for robotics projects. Interpretation of a resource is likely to be contextualized by what a teacher knows of its author—whether this is the first contribution made, whether the author has been teaching for years, etc. The process of adapting a resource or following up on tips or other guidance is also tied to the social network in place, because the network can convey who has been involved in a discussion over some period of time, who has refined or commented on an artifact and so on.

Maps or timelines can provide access to people through their association with projects stored in the knowledge base. For instance, a particular set of teachers might be found by exploring all of the science projects, a librarian via a set of reference materials, and so forth. Social relationships can also be represented more directly in a social network graph, where people are represented as nodes and their relations are conveyed through the distance or links between nodes. Social networks are the underlying structure that transforms a collection of people into a community (Freeman, 2000; Putnam, 2000; Wellman, 2001).

A key design choice in developing a social network graph is defining what comprises the relations among persons. A simple approach is used in the Chat Circles system (Viegas & Donath, 1999), representing members' activity by the size of their associated node. The Babble system (Erickson, Smith, Kellogg, Laff, Richards & Bradner, 1999) attempts to represent more detail about interaction; it translates members' activity into distance from a centerpoint. This coerces multidimensional data into two dimensions, which can reveal interesting structures in the data, but which can also be graphically unstable (e.g., a burst of interactions between A and B could cause the two-dimensional graph to warp substantially). This instability can make such representations visually confusing, but also makes them too dynamic for knowledge navigation (see also Gordin, Farrell & Oblinger, 2001).

TeacherBridge supports people-based knowledge management, but the social networks are conveyed implicitly, not as a directed graph. As illustrated in Figure 4, a teacher looking for new activities or ideas about how to improve her teaching may choose to browse the environment by person. The listing on the left of the figure names each teacher who has contributed activities and experiences; by following these person links, users can learn about the activities these contributing users have explored. Alternatively, browsing such as this can begin at a lower level. On the right of the figure is a view of someone browsing individual projects and their constituent objects in the project and user folder structure. If an interesting object or set of objects is discovered, the user can find out about the people associated with this object by viewing its permission settings. In general, the individuals with both read and write permissions for an object are those who hold the knowledge about how and why it was developed.

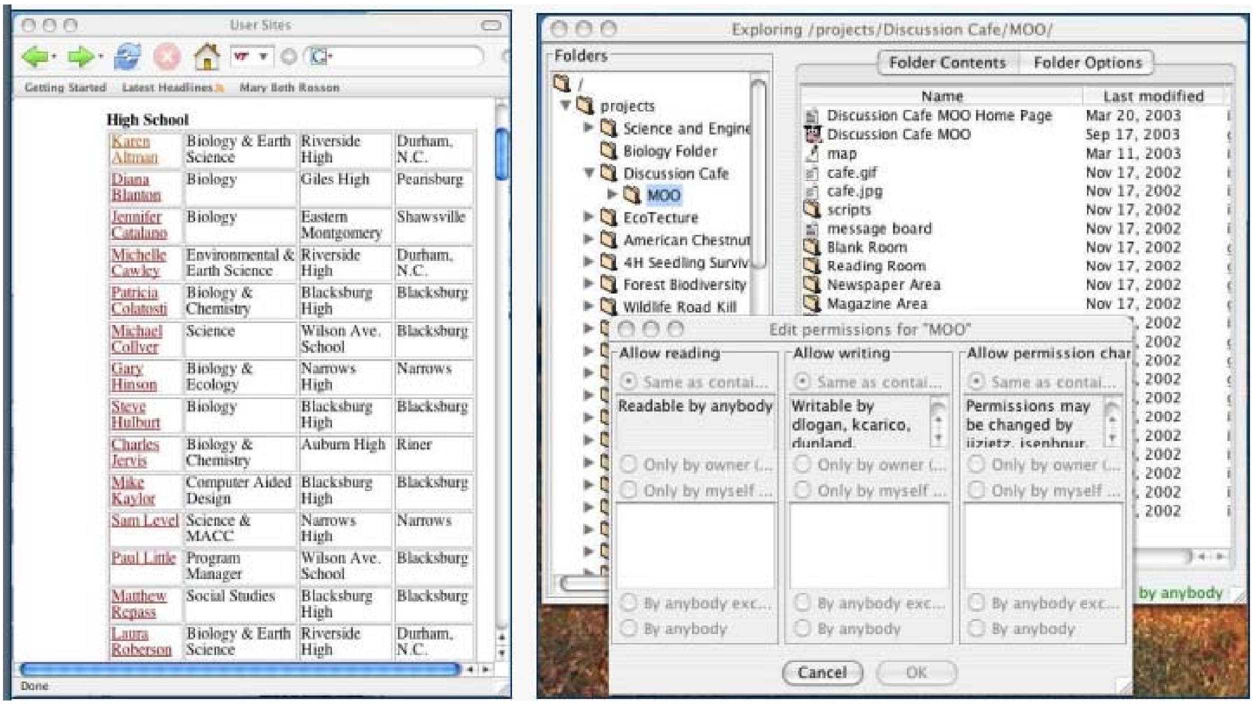

Figure 4. Leveraging social networks within TeacherBridge: the listing on the left advertises participating teachers with hyperlinks to their projects; the folder browsing on the right allows teachers to investigate specific objects and discover ownership through the permissions dialog

We are also considering a TeacherBridge social network visualization that could capture more permanent categories of social relationships, and longer-term communication patterns. For example, the distance between depicted teachers might be a function of the their organizational affiliations, subject-matter focus or grade-level, answers to a social survey (Who is in your closest social circle? Who is in your next-closest social circle? And so on), as well as interaction data (frequency and recency of communication). Distances might also reflect the extent to which corresponding teachers have browsed or downloaded the same shared resources (in a sense, a mutual recommender system). As part of this, we are considering a zooming feature for the social networks, where users can create groups that are represented as single points that a user zooms into to obtain a detailed view.

Social networks are less familiar than maps and timelines, but they are easily understood. A social network map evokes knowledge about the people in the network, memories of shared interactions and activities, and thoughts about what the mapped connections mean and could mean in social contexts. By graphing existing relationships, the network emphasizes the use and strengthening of existing common ground, but it also implicitly raises the possibility of developing closer ties to people more distant in the network.

As she explores the projects in the Pandapas Pond swamp area, the first one Sharon opens lists four different people as authors—a middle school teacher, two high school teachers, and a professor from Virginia Tech. She immediately recognizes the professor's last name (Landay), because it matches one of her students from last year (Jill Landay); she wonders whether they are in fact related. She activates the "Social Network" tool to see what sorts of relationships these four people have with other activities in the system. Not surprisingly, she sees Jill's name and a link to Mark Landay, the Virginia Tech professor. When she moves her mouse over the link between them, she is able to see the nature of their collaboration, another project named "Strubles Creek Underground". She guesses from the project date that this is a project Jill is doing this year, and that Prof Landay must be Jill's dad, grand-dad, or uncle, who is helping out with the project. She also sees that Landay has made contributions to several other projects related to the Duck Pond. Clearly he is very interested in the problems of this area, so she sends him an email asking about his experiences, and wondering if she can offer his name to her students as an expert on the current problems with the Duck Pond.

Discussion

Knowledge management for teachers is challenging because the existing culture of schools is highly individual. But this characteristic is typical of many other organizations. Our approach focuses on tools and techniques for knowledge management that support identifying and acting on opportunities for collaboration, dialogs for articulating and discussing goals, and frameworks for representing and sharing knowledge that leverage the common ground of everyday experience.

Based upon prior and on-going work with two school divisions in southwestern Virginia, we described a requirements analysis for knowledge management support for teachers. We described three levels or stages of knowledge sharing that successively scaffold teacher practices with respect to leveraging resources and one another.

We described four rubrics for representing the knowledge teachers develop and use in their professional activity: place, time, people, and use. We suggested that these representations could support sharing of knowledge and other resources. We illustrated how this might work in a scenario of teacher professional practice.

Our approach is strongly teacher-driven and locally-focused. We started from requirements conversations with a small group of teachers in two school divisions, and even though we have ended up working with most of the science and mathematics teachers in those school divisions, our focus is on the needs and interests of particular teachers and administrators, not on systemic reform at higher levels of the educational bureaucracy. In this sense, our work complements approaches that focus on state standards (e.g., Kuang, Grueneberg & Lam, 1998).

Our current work is focused on validating and verifying our analyses of knowledge management requirements for teachers through a series of participatory design workshops, which continue the long-term participatory design relationship we have established with teachers in these two school division (Carroll et al., 2002).

We are also investigating further representations that leverage people's working knowledge to organize sharable resources. For example, we have developed several alternative map-based representations for place, as illustrated in figures 1 and 2 (Carroll et al., 2001). Concept maps (Ganoe et al., 2003; Novak, 1990) organize objects by various logical relationships. For teachers, the relationships might be "is an example of", "illustrates the same chemistry principles as", and so forth. Task paths (Carroll et al., 1987) are a disaggregated usage representation that organizes objects into a sequence as they are browsed or edited during a work session. The paths can be accessed subsequently to restore a task context, or in our application, to share one's task context with a colleague.

As suggested in the environmental science scenario, it is often useful to have access to multiple representations of a complex information system. In this sense, our frameworks for sharing knowledge are analogous to having multiple views of a program in a software development environment or multiple visualizations of a data set in multivariate statistics. Our investigations of this approach to supporting knowledge management will accordingly also bear on the understanding of the more general design pattern of providing multiple data views in information systems.

Each of the separate views could also be used in concert with one or more of the others. For example, a map view could be augmented to incorporate display of the usage or ownership of objects at locations depicted on the map, or it could be filtered to display only locations with objects created or last-edited within a specified timeframe. Analogously, a timeline view could be augmented to tag displayed objects with an indication of how often they have been accessed, downloaded, or edited, or it could be filtered to display only objects from a particular location or owned by persons in a specified cluster in a social network. What needs to be investigated is whether and how these relatively more complex permutations of the views can be useful to teachers sharing and accessing professional resources.

Acknowledgments

This work was supported by NSF-REC-0106552 and NSF-REC-0353101. An early version of this paper was presented at the Hawaii International Conference on System Sciences in 2003.

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