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Beyond being aware

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A R T I C L E I N F O

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A B S T R A C T

To support collaborative interactions, information systems need to support awareness: Collaborators must attain and maintain reciprocal awareness of shared activity in order to coordinate effectively. Supporting awareness has often been conceptualized a matter of ameliorating deficits inherent in remote interaction. In this paper, we consider awareness support in several community informatics contexts from the standpoint of better-leveraging affordances unique to remote community-oriented interactions. We suggest positive design strategies to design awareness support "beyond" what is typical in traditional face-to-face interchange.

0. Introduction

A well-appreciated requirement for successful collaboration, cooperation, and coordination is *mutual awareness* (Dourish & Bellotti, 1992). People need to know a lot about the people they work with: Where they are. What they are pointing at. What they are looking at. What they recently did. What they are planning to do. How they made sense out of what just happened, what happened a few minutes ago, what happened yesterday, what happened last month. What they know about various relevant bodies of knowledge, and what important skills they have. Who they know that might know something, or know how to do something, that would be critical. And so forth.

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Research on awareness in technology-mediated collaborations has led to a variety of distinctions among different aspects of awareness (for example, awareness of social presence, which might be conveyed among collaborators by a buddy list or a video tunnel, versus awareness of workspace actions, which might be conveyed among collaborators by radar views and shared telepointers). However, most investigations of awareness research have focused on synchronous phenomena: awareness of who is participating in an ongoing activity, awareness of what each person is currently doing in that activity context, and awareness of how the group as a whole is performing. Asynchronous awareness phenomena, for example those supported by version control systems, shared calendars, and project management software, have received less attention.

A typical view of awareness (particularly synchronous awareness) is that it is *disrupted* by technology-mediated collaboration. Indeed, relative to physical, face-to-face interaction (FTF), people using Internet and telecommunications tools experience many deficits: field of view is reduced, the possibility to use gesture is limited, facial expressions are eliminated or constrained, auditory cues are diminished, tools and artifacts cannot be as easily shared, exchanged information is delayed or decoupled by seconds or even minutes, and collaborators may be in different time zones or different cultures. In mediated collaboration it is difficult to convey or discern successful comprehension, current focus of attention, or concomitant attitudes and affect. It is difficult to repair or remediate miscommunications. This transforms awareness into a significant task, which is itself problematic: People are accustomed to taking awareness for granted, as a background task. They do not want to "spend" attention and effort on it.

In this paper we consider struggles to establish and maintain asynchronous shared awareness from the standpoint of *designing with a positive lens* (Avital, Boland, & Cooperrider, 2008; Cooperrider & Avital, 2004, and the other papers in this special issue). The positive lens perspective transcends deficit-oriented analysis identifying and remediating problematic aspects of the world, and instead directs energy toward facilitating and enhancing what is already good about situations. With respect to awareness, we argue that collaborative technologies enhance the mutual awareness of people working together *beyond* what is typical in FTF interaction. More strongly, we argue that the work people must do to establish and maintain mutual awareness can itself facilitate heightened awareness. Thus, instead of being a mere cost of awareness, this effort should be regarded as enabling awareness.

We theorize awareness as a collective achievement with a developmental trajectory. We refer to the mutual awareness of partners in a shared activity of significant scope and duration as *activity awareness.* Activity awareness transcends "being aware", as in my moment-to-moment awareness of where my partner's cursor is pointing. It involves monitoring and integrating many different kinds of information at different levels of analysis, such as events, tasks, goals, social interactions and their meanings, group values and norms, and more. It involves monitoring and integrating more-or-less continuingly to learn about developing circumstances and the initiatives, reactions, and sense making of other people with respect to on-going and anticipated courses of action. As we emphasize below, activity awareness cannot be achieved merely by exchanging state information to explicitly update partners. Such a protocol would be both excessive and inadequate.

The balance of the paper proceeds as follows: First, we review design issues for technology-mediated collaborations, focusing on two classic papers, Olson and Olson's "Distance Matters" (1990), and Hollan and Stornetta's "Beyond being there" (1992). Second, we describe our ongoing investigation of *activity awareness* – a programmatic concept for the collaborative project of constructing mutual awareness in significant activities. The main body of the paper draws from three design cases to illustrate how technology-mediated interactions can enhance the mutual awareness of people working together online relative to FTF, and how mutual awareness is constructed through a continuing process of joint action. These descriptive design cases, in the terms of Hevner, March, Park, and Ram (2004), provide a range of design scenarios to investigate how to go beyond what is possible in a FTF context, to support awareness in new ways in remote interactions. We conclude the paper with a discussion of general design issues and future work suggested by our analysis.

1. Two lenses for design

In technical domains, design is often construed as a sort of problem solving. Such language can seem innocent enough, but even the term problem solving entails a focus on an a priori problem. One cannot do problem solving unless something is problematic. And clearly, design *is* often primarily about problem solving. We gather requirements, analyze them as a problem statement, and then design a state of affairs that responds to, or even solves the problems articulated in the requirements. This is the face of design that looks backward and ameliorates.

Design is also about possibility and opportunity. It is about suggesting new uses through subtle appearances. It is about creating novel ways to engage in familiar activities, and ways at all to engage in entirely new activities. This latter face of design is more vision-driven than requirements-driven, more about exploration than about melioration. It presses a fearless optimism toward the future, weaving the strands of what has not yet occurred artfully enough that some of us will want to go there.

Social interaction, one presumes, evolved over millennia of collocated synchronous endeavor. With respect to all of human history, the possibility of collaborating with others in any way other than direct FTF interaction is a recent development. Direct interaction leverages many situational resources. Olson and Olson (2000) enumerated key characteristics: rapid feedback among collaborators (enabling immediate corrections), multiple communication channels (voice, facial expressions and gestures), access to personal information (e.g., collaborators are ipso facto identified, their locus of attention is visible), nuanced information (e.g., the way a word is spoken, an accompanying gesture or glance can modulate meaning very finely), shared local context (time of day, background noises, ambient lighting), informal interactions before and after task-focused interactions (establishing and renewing social bonds), co-reference (ability to refer to jointly perceived objects and features, use of deixis), individual control (e.g., participants can choose turn taking, pacing, what to look at and when), implicit cues (natural processes like peripheral perception enrich and inform the overall experience), spatiality of reference (ability to use the space in which the collaboration occurs as a resource through pointing and loci).

This sort of analysis is very useful for designers of computer-mediated collaborations. Taking FTF as a sort of "gold standard", it identifies the facets of a problem solving design agenda for collaborative technologies and applications. Each facet can be individually analyzed with respect to how well it meets the gold standard, or is a problem still to be addressed. Indeed, toward the end of their paper Olson and Olson (2000) re-enumerate their key characteristics with respect to how well-supported they are in current collaborative technology and how likely they are to be well supported in future technology. In general, they regarded rapid feedback, multiple channels, personal information, and nuanced information as poorly supported, but likely to become better supported through subsequent technologies. They concluded that other key characteristics – informal interactions before and after task-focused interactions, co-reference, individual control, implicit cues, spatiality of reference – were likely to remain poorly supported and that shared local context, in particular, was not likely remain poorly supported by collaborative technologies.

In contrast, adopted the complementary analytical lens of design as possibility. They were working in the context of the early video-tunnel/media-space projects. Much of this early work embraced an explicit vision of supporting remote interaction as vivid and satisfying as being there. However, at least in the case of video-mediated meetings, this goal was never attained. For example, when users had both FTF and video available, they often used the video channel simply to arrange FTF meetings. Hollan and Stornetta conclude that focusing on the contrast between video and FTF is misguided. If the goal is to imitate, then one can only succeed when one achieves perfect simulacrum. This seems to be an impossibly high standard, but more importantly, Hollan and Stornetta argue that it raises fundamental questions about the enterprise. Why bother to implement a perfect simulacrum of something that already exists in the world?

A more appropriate goal, they suggest, is to explore communication infrastructures that allow and encourage interactions *not* supported by existing technologies and practices. For example, the asynchronous affordances of threaded email permit a new kind of conversation that spans days and weeks and that can be structured in a semi-automatic fashion. They also discuss simple extensions to email that could address well-known difficulties of FTF interaction. For instance, the first response to an issue is normally given inordinate weight in FTF discussions. Asynchronous discussion forums can be configured to batch the posting of responses, perhaps mitigating these groupthink consequences, and taking better advantage of a the full range of responses evoked by an issue (see also Walther's (1996) argument that heightened levels of intimacy, solidarity, and liking might be facilitated by computer-mediated interactions).

Hollan and Stornette's analysis illustrates the application of the positive lens (Cooperrider & Avital, 2004) in design research: They urge an explicit focus on potential affordances, in this case new kinds of social interactions enabled by technology. This contrasts with Olson and Olson's (2000) more engineering-style deficit analysis, enumerating the facets of FTF interaction as a ‘‘gold standard" for understanding progress and open issues in collaborative technologies.

In our view, these are complementary perspectives that are useful to design researchers in different ways. The ‘‘positive lens" of Hollan and Stornetta is especially powerful in helping to articulate new visions for technology – as suggested by their title ‘‘Beyond being there". But unless these visions are tempered by an analysis of potential downsides and risks, they could prove to be disappointing and naïve. For example, asynchronous discussion forums can indeed curb tendencies such as groupthink, but they also are quite susceptible to divergence/topic drift, and flaming. The ‘‘gold standard" lens of Olson and Olson may seem powerful in grounding design research in current social behavior patterns, but it is also limited by its underlying deficit perspective that focuses (merely) on eliminating problems. As emphasized by Hollan and Stornetta, the deficit lens, taken singularly in design, leads to paradox: Why design new things to support only the affordances for interaction that the contemporary world already supports?

2. Activity awareness and the positive lens

In the balance of this paper, we employ the positive lens for design research to investigate and apply the construct of *activity awareness* (Carroll, Neale, Isenhour, Rosson, & McCrickard, 2003; Carroll, Rosson, Convertino, & Ganoe, 2006). *Awareness* is widely described and investigated in research on teamwork and collaboration, and technologies to support teamwork and collaboration. This work has largely focused on *synchronous* aspects of awareness, for example, one's awareness of who is ‘‘present" (social awareness, Dey & de Guzman, 2006); one's awareness of what a collaborator is pointing at or where a collaborator is working in a shared workspace (workspace awareness; Gutwin & Greenberg, 2002), one's awareness of a collaborator's current focus of attention (gaze awareness; Ishii & Kobayashi, 1992), one's awareness of what a collaborator has recently done (action awareness, Begole, Rosson, & Shaffer, 1999; Robinson, Kovalainen, & Auramäki, 2000). In FTF teamwork, the totality of synchronous awareness is sometimes called situation awareness (Endsley, 1995). Synchronous awareness is immensely important to real-time interaction, and, as emphasized by Hollan and Stornetta, by Olson and Olson, among many other researchers, it remains a challenge. Schmidt (2002) provides a good overview of the concept of awareness, particularly with respect to computer-supported collaboration, and compelling plea for a more integrative awareness framework.

During the 1990s, we researched a virtual school infrastructure to enable ambitious project-based activities by groups of middle and high school students across six rural school sites (e.g., Isenhour, Carroll, Neale, Rosson, & Dunlap, 2000). This research context helped to highlight for us awareness issues that transcend moment-to-moment social interaction. For example, collaborators need to be aware of one another's initial and current goals and motivations, of the criteria partners will use to evaluate joint outcomes, of partners' interests, values, and possibly-relevant knowledge and skills, of attitudes towards the current shared plan and the status and trajectory of work accomplished. These issues *cannot* be communicated tout court. Indeed, one of the striking lessons from 20 years of research on computer-supported collaborative work (CSCW) is that people will not, and do not want to share explicit intentional status information (Bannon, 1995; Suchman, 1994; Winograd, 1994). And in any case, because goals, plans, approaches, and other status changes continually through the course of lengthy and complex collaborations, such state information is inherently fleeting. If this were to be managed through explicit status updates, it would require a continual torrent of information, which ipso facto could never be useful or even usable (cf. Carroll, 1990; Carroll, 1998).

In our own design research, we began to distinguish between low-level, mostly synchronous awareness issues, and longer-term issues of group regulation and development. For example, social awareness is directly supported by providing a list of "buddies" and indicating which buddies are present in a collaborative space, and workspace awareness is directly supported by providing a "radar view" of the collaborative space, indicating where each collaborator is currently working. Through our virtual school research, we realized that in use awareness tools like buddy lists and radar views do much more than provide status information about who is around and what they are doing. Buddy list profiles provide thumbnail remarks about a collaborator's goals and activities; collaborators use this information not just to update status with respect to presence, but also to understand how their partners are contributing, and how they and their partners could and should coordinate contributions. Radar views suggest a partner's current information needs, and over time, reveal a partner's priorities and plans. In other words, these awareness tools do not merely ameliorate the *problems* of remote collaboration by displaying state information, they provide new resources, new affordances, new *possibilities* for collaboration and coordination that are not available in FTF interaction.

In framing activity awareness, we appropriated the concept of *activity* from Activity Theory (Engeström, Miettinen, & Punamaki, 1999; Wertsch, 1981), to emphasize that collaborators need be aware of a whole, shared activity as complex, socially and culturally embedded endeavor, organized in dynamic hierarchies, and not merely aware of the synchronous and easily noticeable aspects of the activity. In this view, awareness is teleologically inseparable from collective regulation of a joint endeavor. Members need to be engaged with one another's interests, values, and possibly-relevant knowledge and skills, initial and current goals and motivations, criteria for evaluating outcomes, and assessments of the status and trajectory of ongoing work. This engagement is continually negotiated and developed. We articulated this continual process of activity awareness into four facets, as depicted in Table 1. This is a developmental conception in the sense of Piaget and Vygotsky: higher-level facets are enabled by and resolve conflicts in lower-level facets (for more a more detailed discussion, see Carroll et al., 2006).

Most basically, activity awareness is achieved through the joint construction of *common ground* – shared knowledge and beliefs, mutually identified and agreed upon by members through a rich variety of linguistic signaling (Clark, 1996). Common ground is not a having shared mental model (e.g., Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000); it is participating in a regulatory protocol. Thus, part of common ground is signaling and acknowledging differences, in order that differences among members can become resources to the group instead of risks. Common ground allows members to communicate more effectively, by allowing elision of "given" information, and emphasis on what is "new" (Clark & Haviland, 1977). It promotes group development through feelings of identification and belonging, and through mutual trust and social support. Common ground helps people act together by helping them communicate about activity. In this sense it is always critical to joint activity. However, joint activity also involves transcending explicit communication.

Communities of practice (CoPs) emerge from collaborative endeavors that are already creating common ground (Wenger, McDermott, & Snyder, 2002). The achievement of common ground makes it

Table 1
Four facets of activity awareness.

Facet of activity awareness	Description
Common ground	*A communication protocol* for signaling and enhancing shared knowledge and beliefs
Communities of practice	*A coordination protocol* for developing and applying community-specific practices through enactment
Social capital	*A cooperation protocol* of resource exchanges that engender and sustain generalized reciprocity and trust
Human development	*A group regulation protocol* encouraging innovative decisions and approaches in open-system problem solving to evolve group capacities and performance

possible to develop a shared practice, that is, to articulate roles and responsibilities of members, including recruiting and socializing new members, and to codify standards of conduct and approaches to assessing performance. Shared practice is at least partly tacit knowledge (Duguid, 2005), conveyed through enactment and apprenticeship in activity contexts. Through participating together in work activity—planning and coordinating effort, giving and receiving advice, and evaluating joint outcomes (including diagnosing breakdowns), members continually learn, share, and refine core goals, values, and practices. These functions of communities of practice constitute a facet of activity awareness. Note that higher-order CoP achievements such as division of responsibility are enabled by common ground achievements such as identification and trust, and in turn, enable more complex and ambitious joint projects. Where common ground provides a lightweight and general foundation for collaboration, communities of practice provide a richer and more narrowly scoped foundation.

Collaboration requires more than effective communication and shared practices, it requires shared values and motives (as that term is used in Activity Theory; Engeström et al., 1999); it requires a common framework for thinking about and managing social networks through time. Groups engaged on complex and sustained work tasks inevitably experience stress; powerful social mechanisms must support sustained participation through effortful or divisive episodes. *Social capital* is created through the exchange of resources and support in a social network, and the feelings and beliefs about generalized reciprocity that these exchanges engender in members (Coleman, 1988; Putnam, Feldstein & Cohen, 2003). Members' awareness of this overall framework of shared values and equitable treatment acts as an exception handling mechanism, preserving civility and performance in a group despite occasional conflicts.

When people plan, negotiate and coordinate with others in open-ended endeavors over significant spans of time, when they solve problems that are ill defined and consequential, when they stretch their own capabilities, they develop, that is, they come to experience and interact with the world new ways. In Activity Theory, *human development* is a normal outcome of significant activity, but it is also profound in the sense that it qualitatively changes one's awareness of activity. As an individual develops, he or she becomes more able to understand, to reconcile, and to integrate different levels of performance and different approaches to problems by synthesizing zones of proximal development. The successive elaboration of personal perspectives further enhances each member's awareness of his or her own activity, and creates myriad new ways to construct common ground, codify practices, and build social capital (Engeström, 2008). A shorthand for activity awareness is a group's awareness and regulation of its own activity.

3. Three cases for positive design

We draw from three ongoing design projects to illustrate design ideas for going beyond the awareness possible in FTF settings. Each project is an instance of design research in which we are building and assessing socio-technical interventions as a method of better understanding our underlying theoretical constructs of common ground, CoPs, social capital, and human development. Our level of analysis is the individual and his or her relation to and appreciation of group goals and activities (Korpela, Mursu, & Soriyan, 2001). Although each project addresses different issues and concerns with respect to collaborative work, collectively they expand our analysis of activity awareness and how information technology might enhance awareness. Because the cases draw from different group work contexts, they allow our analysis to cover a broad space of design opportunities and constraints.

3.1. Positioning the cases in a design space

Our three design cases are (1) regional emergency planning (Schafer, Carroll, Haynes, & Abrams, 2008; Schafer, Ganoe, Xiao, Coch, & Carroll, 2005); (2) collaborative case-based learning (Xiao, Carroll, Clemson, & Rosson, 2008; Xiao, Carroll, & Rosson, 2007); and (3) scientific collaboratories built in the context of the CiteSeer scholarly digital library and search engine (Farooq, Ganoe, Carroll, Councill, & Giles, 2008; Farooq, Ganoe, Carroll, & Giles, 2007). These examples of computer-supported collaborative work are useful in mapping out a space of ideas about positive design, that is to say, designing with a positive lens, because they are positioned at different points along several dimensions of group work – distance, social dynamics, and life cycle – that have implications for activity awareness.

Groups of people who are working together FTF are located in the same place and at the same time; this means that they share a physical setting, a central contributor to common ground (Clark, 1996). Thus groups who are not physically co-present must collaborate at a *distance*, without the implicit understanding provided by a shared time and place. Broadly speaking, we can operationalize the concept of distance in groupwork as the proportion of group interactions that are not FTF, the number of time zones that separate members of a group, the magnitude of any perceived cultural differences, and the degree to which members belong to a CoP. Even for groups in the same organization who work at the same site, distance is increased if collaboration occurs largely through email or other communication technologies. To measure common ground in such situation, for example, communication structures and recall of task information can be used to assess the extend of common ground (Convertino et al., 2008). A distributed group may conduct most of their activities online but come together on occasion for FTF interaction; such meetings can be critical to establishing or re-establishing common ground. Furthermore, distance is increased not only by physical factors (time and space) but also by socio-cultural factors (organizational or national culture, shared professional practices; Chatman, Polzer, Barsade, & Neale, 1998; Plotnick, Ocker, Hiltz, & Rosson, 2008). If members are not already part of a CoP, physical separation will inhibit the development of shared practices, because a dispersed community has less opportunity for situated observation and learning.

Social dynamics refers to the presence or emergence of social structuring relations and their consequences for interaction. One way to qualitatively assess the presence of such structures would be to determine whether a group has articulated a framework of roles and norms (see Resnick, 2002 for details regarding different forms and measurements of social capital), and whether these roles and norms are associated with protocols for intra-group communication and activity coordination. The social structuring relations present in a group lead to patterned behaviors within a CoP, as members are assigned or choose to align themselves with different roles and responsibilities (Capobianco, Diefes-Dux, & Oware, 2006). Social dynamics are also related to the groups' ability to build social capital, because structuring relations like leadership can mediate the requests and responses that are generated within the group. With respect to human development, groups that contain a diverse set of social structuring relations offer members with many opportunities to observe, learn, develop, and take on new roles (Vygotsky, 1978).

Finally, groups evolve through a *life cycle* that is determined by its members' interaction history and the developmental trajectory the group is following (Arrow, McGrath, & Berdahl, 2000). The operational factors in this case are time since formation, history of prior interaction (what McGrath, 1991 calls the "standing group"), and the timeframe for the current shared goal(s). For example, some groups come together and work quickly to solve a specific problem (e.g., a task force), while others work together over long periods of time, with the intensity of their collaboration rising and falling as a function of the currently active project(s). Some groups have a clear point of formation, while other gradually come together over a period of time before they take on a focused project. But whatever history a group has, it represents shared experience and contributes to common ground as the group forms and collaborates (McGrath, 1991). The life cycle of a group clearly also places constraints on CoPs, social capital, and human development—it takes time to develop shared praxis, mutual respect, and to recognize and respond to opportunities for personal growth.

Table 2 considers how these three group work dimensions differ in interesting ways across the contexts of the three design cases, and summarizes how such variations are related to common ground, CoPs, social capital and human development. In the balance of this Section we elaborate on these connections between the group work dimensions and the facets of activity awareness; in Section 4 we consider the implications that these connections have for design support that goes beyond activity awareness.

In the emergency planning design project the group members collaborate to provide an important civic function. We are developing and evaluating a shared map-based planning tool that assumes and supports experts with differing expertise (e.g., civil engineers, mass care experts, environmental planners) in coordinating and prioritizing concerns and plans in "tabletop" exercises (Convertino, Ganoe, Schafer, Yost, & Carroll, 2005; Schafer et al., 2005, 2008). The online collaborations that we envision for

Table 2
Groupwork dimensions and facets of activity awareness addressed by the design cases.

Facet of activity awareness	Distance: *What factors contribute to distance among members*	Social dynamics: *What social structuring relations create patterned behavior within the group*	Life cycle: *How long has a group been together and how rapidly must it cohere and develop*
Common ground	Regional emergency planners share a physical geography, but do their work online	Regional emergency planners include volunteers who have less background in the planning process	Scientists share new ideas through long-term analysis and synthesis of their own and others' work
Community of practice	Student projects are physically and culturally removed from usability engineering professionals	Regional emergency planners include volunteers whose contributions may be devalued relative to those of the permanent staff	Regional emergency planning involves a regular influx of volunteers whose background must be assessed and accommodated
Social capital	Regional emergency planners share situated information associated with geographically distributed locations	Regional emergency planners may also be neighbors or co-residents of a real world community Scientists create implicit structuring relations by selectively reading and citing others' work	
Human development	Scientists develop careers via distributed efforts at research and publication, with only occasional FTF debate and re-calibration		Student projects start quickly and develop in an intense fashion according to a class schedule

this group are interesting with respect to activity awareness, because even though the group will meet online to do its planning, their daily lives take place in a shared physical setting that provides a starting point for place-specific planning issues. At the same time, individuals with situated knowledge (e.g., about specific road work) are expected to contribute such information when relevant. The shared physical setting also engenders a set of community-based social dynamics – members may be neighbors or co-residents, such that they build social capital within their community through their shared work on emergency planning.

Another characteristic of emergency planning teams is that they typically include both permanent staff and volunteers. This social structuring relation influences common ground, in that volunteers typically bring less expertise with emergency planning to their understanding and participation in group discussions. This relation also has implications for CoP; because volunteers have less history with the team, their contributions may be seen as less central and thus less likely to represent or influence group praxis. Finally, the recruitment of volunteers influences the processes of member development. Some members are long-term participants, but there is constant turnover in membership. One result is that the group must constantly be assessing what new volunteers do and do not know, bringing them "up to speed" as needed.

The context for our case-based learning project is a university course on usability engineering. In this class, students form groups and work together on projects to learn about and practice the skills of professional usability engineers (Rosson & Carroll, 2002). A notable feature of this design context is the team's life cycle: the student groups are short-term and very focused on a timeline of project deliverables (somewhat akin to a "task force" in professional work contexts; similar to the groups studied in Gersick (1988)). They must cohere quickly as a group so that they can learn about and develop team roles and practices related to usability engineering. Distance also is a factor here, in that the student teams are developing their practices in a context that is both physically and culturally removed from the real world of usability engineering. As a surrogate, the students study real world case studies to help them discover and emulate professional practices in a short amount of time (Carroll et al., 2006; Xiao et al., 2008).

The third design case is our most atypical example of groupwork, in that scientists who contribute to a research arena may not even identify themselves as a group. Researchers who work on related topics may belong to professional organizations that host regular meetings; through social networking at such events, they may come to affiliate with these organizations. However we suggest that in addition to explicit affiliations of this sort, scientists collaborate implicitly over time through shared critique, synthesis, and evolution of their fields (Moody, 2004). An interesting feature of these implicit collaborations is their life cycle; the ideas that create a research community's common ground emerge and become accepted through a relatively slow and formal process of scientific review, publication, and citation. With respect to distance, the work of these communities is primarily distributed, with most of it carried out in individual labs, evaluated through peer review, and only occasionally presented and debated in a FTF forum (the frequency of such forums depends on the speed at which the research area is evolving). Finally, with respect to social dynamics, scientific communities use a distinctive mechanism for creating social structuring relations – citations. Although scientists may become friends or colleagues, the most pervasive connective link is citations. Scientists select whom and what to cite and by so doing, they create implicit provider-consumer relations between themselves and others in the field, contributing to the social capital within their community. Our design project on scientific collaboratories is seeking to leverage the distributed and implicit relationships that are present in research communities, making the connections more available and useful (Farooq et al., 2007, 2008). In this design context, the focus for activity awareness concern is not on a group project per se, but rather the more general activity of developing a scientific community.

3.2. Design research methods

Our design research projects are not traditional empirical studies, in the sense of sampling and summarizing representative real world data. Nor are they purely theoretical; we rely on theoretical discussions of activity and collaboration, but primarily by applying the ideas to the development of more useful and usable information systems. In line with the arguments advanced by Hevner et al. (2004) for design science, each case can be seen as a synthesis of design ideas that are drawn from both theory and empirical data, and that are refined through analytic and empirical evaluation. Our focus is not on pushing the information technology envelope, though we do integrate emergent techniques if and when they make sense. Rather our emphasis is always on questions of activity design; such questions often involve novel applications and socio-organizational appropriations of familiar technology. Each of these design projects are still in progress, as we iteratively refine our ideas through requirements analysis, design scenarios accompanied by tradeoff analysis, prototyping, and user studies (Carroll, 2000; Rosson & Carroll, 2002).

In the emergency planning case, we have relied extensively on field work with regional emergency planners (Haynes, Schafer, & Carroll, 2007; Schafer et al., 2008) in developing our design ideas. For instance, we have participated in FTF tabletop planning exercises and interviewed key stakeholders. We observed many challenges in managing the planning process, including the highly distributed organizations who participate, the specialized expertise they bring to the process, the logistics of scheduling and running the tabletop planning activities, and the subsequent problems in getting the formal planning documents updated. We began to work on a collaborative geospatial system that could support the group in both synchronous and asynchronous collaboration. As design ideas emerged, we have gone back to the stakeholders for participatory analysis (Carroll, Chin, Rosson, & Neale, 2000). At the same time we have been prototyping the design proposals and have begun to gather extensive empirical data on the effectiveness of the techniques, using a combination of paper and computational prototypes.

For our work on collaborative case-based learning, we began by studying individual learning activities using an existing repository of usability case studies (Carroll & Rosson, 2005, 2006). We developed collaborative versions of these activities and observed the student groups' in-class interactions and collaborative products; we also collected feedback about the new activities with post-activity surveys. More recently we have explored the use of an earlier prototype in group projects that included usability engineering activities with real world customers. We have used these data in concert with theoretical analyses of collaborative and case-based learning to motivate the design of our current prototype (Xiao & Carroll, 2007).

For the scientific collaboratory project, our design work has been guided by user studies conducted with users of CiteSeer, a search engine and digital library of research literature in the computer and information science (CIS) disciplines that is a free public resource (Giles, Bollacker, & Lawrence, 1998; Lawrence, Giles, & Bollacker, 1999). CiteSeer provides access to full-text versions of nearly 700,000 academic publications, and over 10 million citations; it receives more than half a million hits a day. As an example, we conducted a user survey eliciting requirements for enhancing the digital library into a collaboratory (Farooq et al., 2008). In a follow-up study, we asked users to give feedback on prototypes for supporting various awareness mechanisms (Farooq et al., 2007). In other work (Carroll & Farooq, 2007), we have suggested several design enhancements to CiteSeer's infrastructure to support user collaboration in general.

With these three design research projects as background, we turn now to a discussion of the specific strategies for enhancing activity awareness that we are investigating under the lens of positive design. Although our design ideas have been inspired to a great extent by existing literature and our own empirical investigations, the positive lens has provided a useful analytic perspective for considering design implications in a more systematic way. Some of this design work echoes the proposal of Hollan and Stornetta to go beyond, in that we consider how computer-mediated collaboration may enhance activity awareness in ways not possible in FTF activities. Other ideas can be seen as a counter to Olson and Olson's concerns about the costs of computer-based communication, in that we illustrate how the extra costs of remote collaboration can produce additional benefits with respect to activity awareness.

In Sections 4–7, directly below, we present a series of examples drawn from the three design cases, each illustrating how we used positive design to enhance various facets of activity awareness relative to well-established FTF interactions.

4. Design possibilities for common ground

4.1. Coordinating private and public views

During 2004–2006, we shadowed and interviewed the Emergency Management Coordinator of the Centre Region Council of Governments (Pennsylvania) to better understand work practices and opportunities for information technology interventions in this work (Schafer et al., 2008). Regional emergency planning is highly distributed among a number of local organizations (e.g., emergency managers, firemen and police officers, public transportation officials, municipal governments, and local businesses). The planning is also role-based, because each organization holds specialized knowledge about its area of concern. Public works experts are responsible for roads and bridges, emergency medical service units for aiding the injured, public information offices for news reports, and so on. Often the relevant knowledge is extremely local: how to get from point A to point B when a certain road is out, the closest doctor to a given location, where particularly vulnerable individuals reside.

To a great extent, the emergency planning is accomplished through FTF collaborations around large tabletop maps; secondarily, a document-oriented process is used to codify the plans. Through these interactions, emergency personnel exchange knowledge and build common ground, both by increasing the knowledge shared, and by increasing awareness of who knows what unique information that may be critical. The FTF collaborations are constrained by the need to get so many stakeholders into a room to engage in plan development. The documentation process is sometimes cumbersome because of difficulties in updating, circulating, reviewing, and collating plan revisions. These are significant impediments; regional emergency managers we interviewed have perhaps one or two all-hands meetings per year, and they know that many of their planning documents are out of date but lack the resources to undertake massive regular updates (Schafer et al., 2008).

We envisioned a system to support this work using a geospatial information system with multiple map views, as in Fig. 1 (see also Convertino et al., 2005). Emergency specialists fulfilling different roles can maintain and mark up distinct views of the map, but can also export or share their work in the group map. For example, a public works specialist could indicate on a private map which roads and

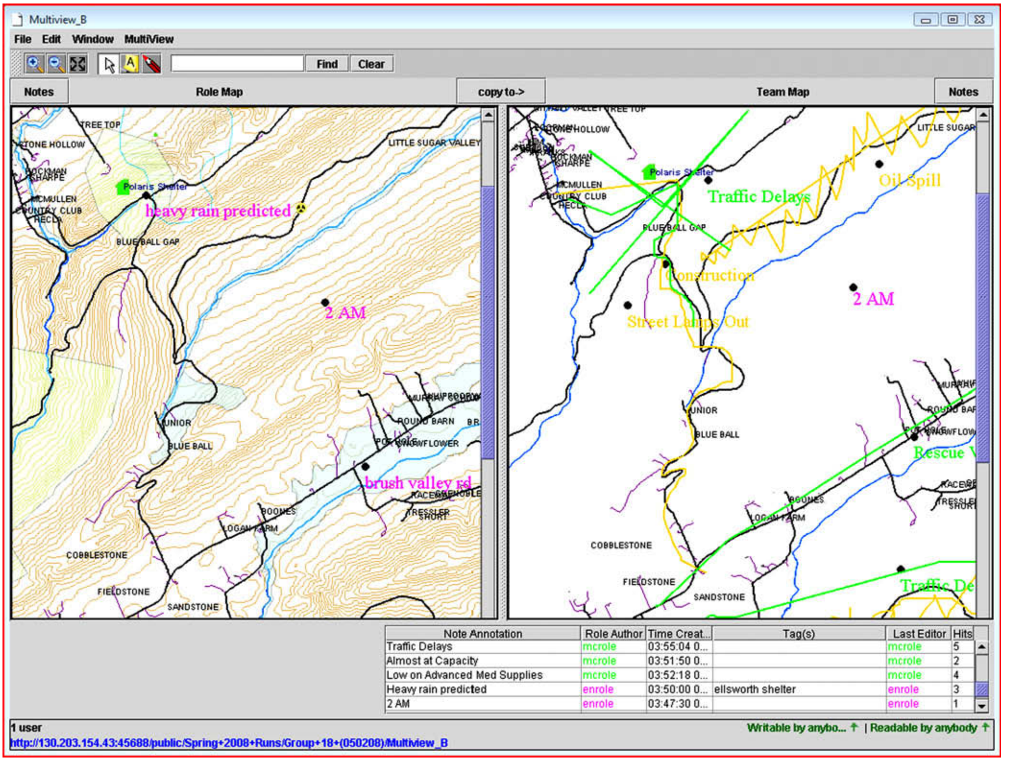

Fig. 1. A multiple view interactive map prototype for regional emergency planning. The map view on the left is for an environmental specialist; for example, it indicates topography and flood plains. The map on the right is the group-level map and shows annotations made by different members. At the bottom is a table view of notes that have been shared.

bridges are critical for a given planning scenario, while an environmental specialist could indicate where flooding is most likely to occur. The planners can annotate and develop their own map views, importing ''private'' annotations into the public view as useful. Planning of this sort can be carried out synchronously or asynchronously; it can occur throughout the year, anytime of day or night. Stakeholders who cannot join a given synchronous interaction can catch up later. We have demonstrated this software to the Centre Region Emergency Management Coordinator, who has agreed to adopt the software for planning and training purposes.

The concern for common ground in emergency planning settings is intense. Collaborators must make plans for ill-defined threats whose consequences could literally be matters of life and death. They must integrate disparate sources of expertise, and vast, albeit somewhat idiosyncratic knowledge. Common ground must be established ahead of time through emergency planning in order for an effective and efficient response during a time-critical and chaotic event in which responders with differing expertise will most likely need to synthesize their knowledge and skills to make best use of whatever resources are available. But for this to happen, emergency personnel must have a sufficient opportunity to engage in collaborative planning. They need to be able to develop sufficient mutual understanding to warrant the trust they may need to save other lives and even their own lives.

The prototype in Fig. 1 enhances the planners' options for establishing and monitoring common ground in several ways. At its most basic level, the system provides transparent support for a role-oriented communication protocol that is distributed in time and place, so that stakeholders who hold critical knowledge but are unable to attend a given FTF meeting can still make and benefit from contributions. The private and public maps are persistent; this means that when planners do meet FTF, they can access work done previously by themselves and other colleagues, regardless of when and where the earlier planning took place. There is no need to plan and later re-plan because a critical person is missing. These benefits rely on familiar affordances of computer-based collaboration – a persistent task-oriented representation supports an inherently distributed and localized knowledge-sharing process.

A more subtle example of positive design inheres in the contrast of private and public views. The simple presence of a personal view acts as a reminder to each planner that he or she may have role-specific knowledge to share with others in the group; the view is a constant invitation to think about, annotate, and decide whether and when to contribute their specialized emergency-related knowledge to the common ground. At the same time, the private view reduces the cost of sharing, because the potentially useful information can be held temporarily in an intermediate location, until the planner decides that it is pertinent to the plan being developed.

4.2. *Mining patterns of knowledge sharing*

Much of the common ground in scientific collaborations is created in a process that is indirect, distributed, and extended in time: Scientists may identify new potential collaborators by hearing presentations at a conference, reading journal papers, or hearing about new work in a conversation with someone else. More generally, they discover and read relevant new papers, reason about new findings or anomalies, develop and pursue new ideas, and eventually submit their own results for peer review and publication. Thus particularly within a discipline, scientists share considerable knowledge even before they meet, and can leverage this in their initial steps toward more direct collaborations. Common ground may be signaled or tested by mentioning a recent citation, or raising a pointed question that assumes a specific background reading.

The fact that published research plays such an important role in scientists' common ground is a starting point for our positive design efforts in scientific collaboratories. Specifically, we are exploring techniques for capturing and visualizing characteristics of scientific work that can build on and enhance this already-established protocol for maintaining common ground. For instance we are exploring social bookmarking services in the context of the CiteSeer user population, allowing scientists to organize a collection of resources with personal keywords or tags and share their classification system with others.

Social bookmarking services are an increasingly popular Web phenomenon, evidenced by the online explosion of web sites like Delicious (http://del.icio.us). Recently, social bookmarking websites have started to emerge for academic communities as well (e.g., http://citeulike.org), but no empirical investigations have been carried out to determine how the visual analytics offered by social bookmarking can be useful to users of scholarly digital libraries. We speculate that users of scholarly digital libraries will find social bookmarking services useful for reflecting on their own intellectual practice (''how popular or stagnant is my current research focus'') and analyzing trends over time (''a particular research area is ramping up in the field''). Social bookmarking has the potential to aid knowledge discovery of new and relevant online content and to support collaborative search and retrieval tasks (Millen, Feinberg, & Kerr, 2005).

The pattern-mining services of a tool like CiteSeer can also be recruited to enhance knowledge sharing with respect to new events happening in one's field. To achieve this, scientists need to be aware of each other's activities – who is doing what, when a digital resource of interest has been updated, when their own work has been cited by others, and so on. By broadening activities that are offered by CiteSeer from ephemeral search tasks to more sustained and long-term interaction, we can enhance scientists' awareness of the ''buzz'' in their fields.

Fig. 2 presents a simple example of how CiteSeer users might use a mechanism like RSS (an acronym for Really Simple Syndication) to ''watch'' for activity related to published literature of interest to their own knowledge work. This is the kind of awareness that scientist try to maintain on their own by browsing new papers, going to conferences, and so on. But they can never manage the comprehensive analysis possible through a simple mechanism like RSS combined with a digital library service like CiteSeer. While a manual search on ''tactile interfaces'' might retrieve all instances of this phrase in the site's database along with information about who wrote the articles containing the phrase, our

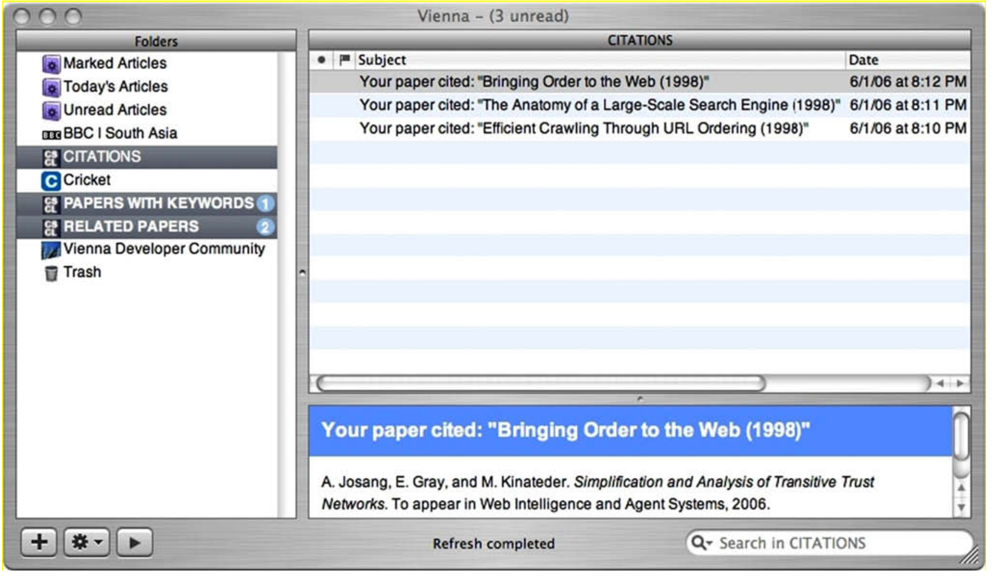

Fig. 2. A prototype of RSS feeds for CiteSeer that aggregates notifications to users for three publication events: (a) citations to their papers; (b) papers that have user-specified keywords; and (c) related papers to papers that users have published.

design would do more by aggregating information over time. This creates awareness of whether topics are active now or in the past, who else is publishing or searching for information in an area, and whether these potential collaborators are active now or in the past.

5. Design possibilities for communities of practice

5.1. Emulating expert practices

Part of activity awareness is the development and maintenance of communities of practice. Novice community members learn these practices by observing and modeling on the behaviors and values of more established members. But in the case of "student members", the target community is not directly available. For a number of years, we have been exploring techniques that could allow students in a university setting to "visit" the CoP and to experience vicariously its goals and practices. As part of this, we have been using case-based learning method in an undergraduate course in usability engineering: students explore cases that report the real world experiences of usability engineering professionals. Students increase their understanding and skills in this problem area by reading and thinking about the cases (Carroll & Rosson, 2005, 2006; Rosson, Carroll, & Rodi, 2004).

Building from our framework for activity awareness, we are using positive design techniques to expand and to scaffold students' awareness of the practices that are possible and relevant within a professional community. In the usability engineering course, students study one or two cases prior to class; they react to the cases using a collaborative tool for browsing and commenting. Each student analyzes a case from the perspective of usability engineering role assigned to him or her (e.g., product manager, designer, or customer; see Fig. 3). In class the students break into groups to analyze the implications of their comments with respect to a requirements "perturbation" (e.g., the user audience is expanded to include children). They discuss the case study, role-playing members of a software development team confronted with a changed requirement. They are asked to enact the values and practices of the CoP of professional usability engineers operating in a problem context. Each time they do this, the students are working to appreciate and emulate the values and skills of expert usability

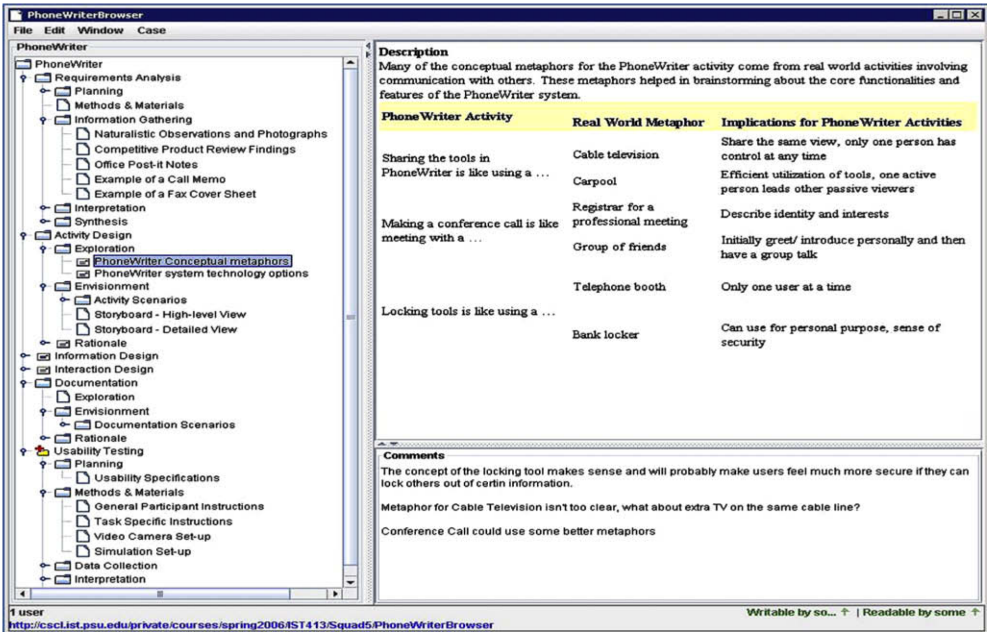

Fig. 3. A screenshot of the collaborative case analysis tool used by a student group for role-based analysis of the Phone Writer case study of usability engineering.

engineers in the case study stories, which they can subsequently apply to their group semester projects. Over the course of the semester, each student emulates different roles embedded in different contexts of professional practice.

Real world case studies are promising as a mechanism for raising awareness of CoPs in a classroom setting. Of course the general idea of sharing expert behavior has been noted before, as in Orr's discussion of "war stories" for knowledge management (Orr, 1996). But we show how this relatively simple concept can have a transformative effect in the classroom, bringing experiences to students that they could not have had otherwise. The assignment to first review and then role-play the perspectives of different experts adds a collaborative cost to the learning activity, but the result is an enriched view into the practices and values of the CoP. Reading about and commenting on real world cases sensitizes students to the real world of tradeoffs in design; requiring them to emulate the separate perspectives of different experts enhances their awareness further through emulation of role-based discussions and argumentation.

5.2. Incidental organizational memory

The term "emergency" connotes frantic activity in dire circumstances. But much of effective emergency response has nothing to do with speed or courage, but rather with making sure the right person enacts the right practices at the right time and in the right place. Emergency responders spend most of their work time planning and preparing for emergencies. However, especially in smaller communities and rural regions, these organizations rely on a mixture of professional staff and volunteers. Inevitable, sometimes rapid, turnover in volunteer members creates major challenges in creating and maintaining organizational memory. Community members do not volunteer to be firemen because they want to codify procedures and other organizational knowledge. People do these things because they believe in the purpose of the organization; this is a powerful source of motivation, but it is directed at the primary function of the organization, and not at the ancillary information management tasks that are critical to all organizations.

Civic organizations are particularly challenged with respect to the general problem of underdeveloped organizational memory. Volunteer members depart from civic groups more abruptly and less discretely than employees do from business organizations. There is no final paycheck; sometimes people just stop showing up, or show up less frequently. The intrinsic motivation and interest in the group's mission is a significant positive for local community groups, but it pushes responsibility and critical decisions to lower levels in these organizations: A volunteer fire company is more like a club than it is like the Army. Our field studies of community organizations have documented several cases in which a critical individual departed and inadvertently left a critical knowledge-hole in the organization (Merkel et al., 2005). When this happens in the local historical society, it is an organizational crisis, but when it happens in a fire department, it is a community disaster.

Our field study of regional emergency managers (Schafer et al., 2008) revealed that top-level planning is explicitly managed and codified, though it tends to rapidly slip out-of-date and is not continually maintained. Individual emergency organizations, like fire departments, do work on maintaining their own knowledge assets, but this work tends to focus on internal practices rather than how the group coordinates with other emergency organizations. For example, the fire department attends to knowledge about fire safety and response, but somewhat less so to knowledge about how the fire department should coordinate with airport officials during an emergency at the local airport, or with other regional fire departments during a large-scale emergency. The social dynamics of regional planners who must integrate multiple sources of expertise are a driving factor—the salient requirement is to manage organizational knowledge management for one's *own group*.

Under the lens of positive design, these social and organizational dynamics of community service organizations are not problems to be solved, but a resource to be better utilized. In Section 4.1, we described how a collaborative geospatial system can integrate emergency planning across different sources of knowledge, enhancing awareness of common ground. Here we observe that the digital detritus of this planning process comprises *incidental organizational memory*. The residue of planning—and associated organizational memory—around paper maps rapidly degrades. This motivates a secondary process of consolidating the planning events as paper documents. But digital plans will not degrade in the same way or to the same extent: Map mark-ups can be saved in libraries and even the process data from map annotations can be saved. These ideas are analogous to Ackerman's work on Answer Garden, an organizational memory system for help line staff (Ackerman, 1990); that system recognizes the value of storing and providing access a continuing stream of questions, many of which occur over and over, or can be repurposed or adapted to new situations.

We do not regard this design idea as Q.E.D. (*quod erat demonstrandum*). Many questions remain concerning whether and how saved maps and map interactions could be effective as a resource for organizational memory: Merely creating records is not the same thing as constructing effective support. For instance, our laboratory studies of simulated distributed emergency planning have documented the separate contributions of both content and process when building common ground (Convertino et al., 2008). We do not yet know how best to capture, integrate, and convey these two different elements of a planning process, especially in a way that will make them convenient to browse and understand. We are pursuing this in our work with the Centre Region Council of Governments, by using our geospatial system to support planning activity, and then using the artifacts of that saved activity to present training scenarios to new members of Centre Region emergency organizations.

6. Design possibilities for social capital

6.1. Visualizing exchange networks

A variety of collegial processes build social capital within disciplinary communities of scientists. For example, scientists interact with and support their peers by collaborating directly on projects, reviewing (or receiving review of) their work, organizing or attending research meetings, writing reference letters for awards or promotion, and so on (Moody, 2004). However, when viewing these as social capital exchange processes under the lens of positive design, we see a broader set of scientific acts that can also build social capital, but that are not likely to be realized through existing social networks.

Currently scientists stay aware of their peers' research activities through personal contacts (e.g., at meetings or through friend-of-friend links) or through the more formal processes of scientific review and publication. These mechanisms are naturally constrained by the breadth of a scientist's professional network, and typically are limited to relatively direct interactions surrounding his or her personal research interests. But if we can give scientists a more expansive view of scientific exchange – one that is implicit in use of bibliographic tools like CiteSeer – they may become aware of relevant research activity *outside* their normal sphere of interaction and influence. This particular design strategy builds on Granovetter's (1973) notion of *weak ties* that are not exercised frequently but that may provide useful social resources if one becomes aware of them at just the right time.

We are exploring several sorts of CiteSeer interactions that might contribute to a broader appreciation of social capital in scientific work. For example, a scientist using a digital library like CiteSeer might discover activity-based social networks through shared queries (who has submitted queries like this one?); through citation patterns (who do I cite or who cites me?); or through content matching of papers (whose has published papers that contain research results similar to mine?). Second-order networks (what papers are related to papers that are related to my papers?) could also be valuable in breaking down boundaries among research sub-communities. A schematic diagram of collaboration discovery through query patterns appears in Fig. 4, illustrating how weak ties might suggest fruitful social processes. The surfacing of weak ties such as this might help scientists to become aware of new possibilities for research collaboration or advice based on similarities in *online* behavior, something that is not possible in FTF interactions.

A similar design technique would be to draw suggestions from citation networks. Studies of scientific citation often question whether it is *who* or *what* the authors know that drives citation. White, Wellman, and Nazer (2004) analyzed this question deeply in a case study of citations and concluded that scientists tend to cite those who co-cited with them in other papers. This suggests an approach to expanding a scientist's awareness in include more "removed" work, as envisioned in the following CiteSeer scenario:

> *For his upcoming tenure review, James goes to CiteSeer to estimate the number of citations to his journal articles. He sees a long list of citations: he recognizes many author names, but not all. He is curious whether and how the people citing his work are connected in other ways. Analyzing his citation network in detail, James discovers that some of his citers also cite Alistair Komer's work on value-sensitive design. When he investigates Komer's work, he sees research questions that are similar in many ways to his, but that Komer publishes in a research community focused on nonprofit community processes. James is surprised he has never heard of Komer's research, but is excited to discover it and to integrate it with his own.*

In this scenario, James discovers potential collaborators through CiteSeer's citation network. From its database, CiteSeer affinity discovery algorithm was able to extract frequently co-cited authors for a given person. This leads James to identify Komer as a potential collaborator from a different research community that otherwise he might not have known about. Fostering such inter-disciplinary collaboration can lead to an enriched view of research concepts and articulation of novel research trajectories.

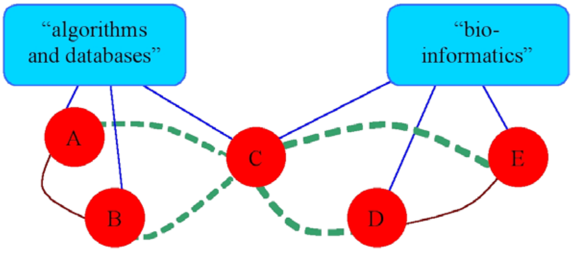

Fig. 4. Users A, B, and C are connected to each other implicitly in an affinity network derived from the two queries, "algorithms and databases" and "bio-informatics". The connections of C, D, and E are based on their shared query of "bio-informatics". Users A and B are connected to D and E through C, who shares both queries.

Both the shared query patterns and the co-citation networks are techniques for aggregating information about scientific acts – research questions in the first case, research recognition in the second. They build social capital by enabling researchers to better appreciate their similarities and shared intellectual capital, forming and strengthening professional affinity bonds. Exchange networks like these are part of the ongoing process of scientific development, but are difficult to appreciate directly. Digital library tools like CiteSeer enable a new set of computer-mediated options for surfacing information about these more subtle collaborative activities.

6.2. Situating resource networks

Emergencies are unexpected events. A major factor in planning and managing emergencies are the unknowns of timing, specific location, and severity. A paradox of planning in emergency domains is that while no plan will probably ever be followed as such, it is essential to have well-developed and well-practiced plans (cf. Suchman, 1987). All emergency responders need to know what their responsibilities are in a crisis; they also need to know when, why, and how to modulate what they do, including who they must coordinate with in doing so. The planning and training that emergency organizations conduct not only prepares members for this sort of improvisation, but also nurtures collective efficacy, trust, and social capital among the collaborating organizations and their members: Not following a shared plan has a social cost, particularly across different organizations.

Of course, even when a shared plan is *followed*, there may be social costs across organizations. For example, police may need to redirect traffic at an emergency scene, but this can have direct consequences on how fire companies or EMS units can get to and operate around the scene. Similarly, diverse response units may be staged near an emergency site, needing to use the same roads to move to and from the site. In these examples the different organizations create constraints on the functioning of their partner organizations, and must plan for these coordination requirements in planning, and in practice – including the improvisation of real operations. The planners must be able to both recognize and anticipate the situational details that are (or will be) distributed throughout the geographic area they are supporting.

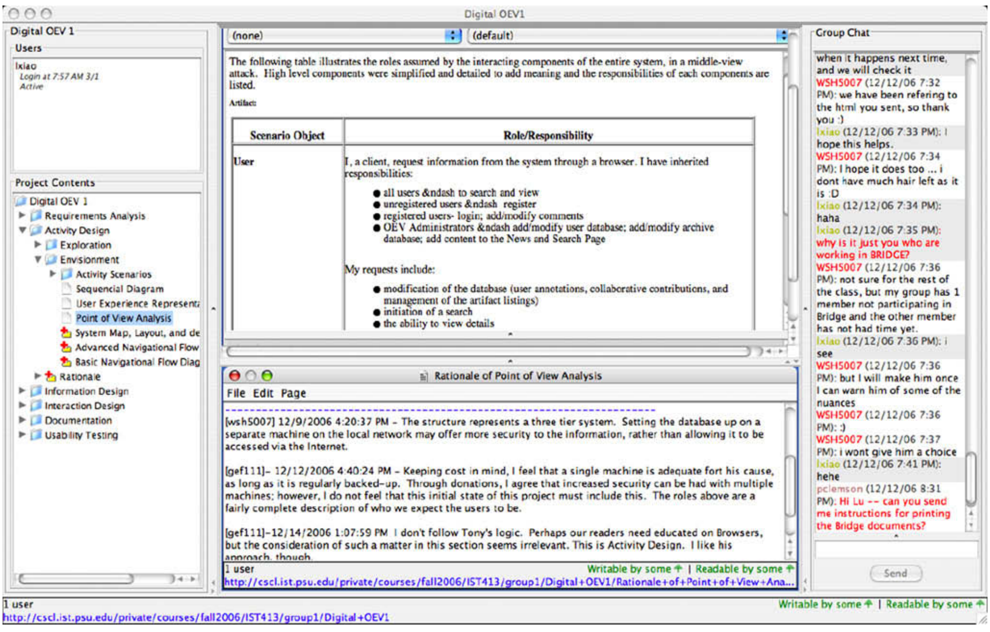

Fig. 5. Collaborative tool for students to build, refine, and reflect on their class projects as instances of usability engineering case studies.

In our design work, we are exploring techniques for helping planners to highlight the costs and benefits of the options they are considering or have recommended in complex emergency response planning scenarios. Currently we are enhancing the collaborative geospatial information system to allow the planners to attach bits of situated rationale to the suggestions they make. For example, a planner might submit rationale for a particular map annotation noting that a default rescue route should be avoided because a power line just came down; or that a secondary route is preferred because several large-capacity trucks happen to be in the vicinity. Supporting the posting and viewing of situation-specific rationale during the planning creates in group members an expanded awareness of the overall emergency response task (simulated or otherwise) and enables them to make more appropriate requests or denials of plan deviations and other shared resources. Over time, the mutual recognition among stakeholders that they understand the big picture and its implications contributes to the group's social capital and trust in one another's improvisational capacity.

7. Design possibilities for human development

7.1. Visualizing the value of contributions

In scientific discourse, researchers constantly evaluate and re-position their work as a function of what others in their community are contributing and how their peers are reacting to their own contributions (Moody, 2004). At times, they may receive targeted critiques or suggestions (e.g., at a research workshop or professional meeting). But because of the distance separating most members of a research community, the primary mechanism for scientists' self-evaluation is publications – thus a first-order task for all researchers is to stay abreast of their field's publications. Researchers build and refine their perceptions of their own positions within their communities by tracking the publication success of themselves and others.

Self-reflective services in scholarly digital libraries might help a scientist to go beyond current practices for monitoring, calibrating, and responding to the impact of his/her publications on a field. For example, suppose that in addition to tracking actual publications, CiteSeer was able to track and visualize the *preparatory* activity leading to a publication. This possibility is not far-fetched; computer science researchers have a long tradition of making documents available on the Web in the form of technical reports, submitted papers, and so forth. Continuing the example, suppose that CiteSeer tracks and analyzes not only citation patterns in published papers (as discussed in Section 6.1), but also those for works under review or in progress (anonymously of course). A broadening of researchers' awareness in this fashion might promote human development in at least two respects: The self-efficacy of researchers working in a given area might increase as they recognize that many others are "struggling" with related concepts. Furthermore, researchers' motivation to pursue a difficult topic might be increased if and when they become aware of others' interest and efforts.

Another design possibility relates to the different roles played by the members of a scientific community. Elsewhere we described the characteristics of *developmental* learning communities (established phases of development and the shared goal of promoting growth through these phases; see Rosson & Carroll, 2003, 2006). Scientists working within a discipline comprise a developmental learning community that may include interested observers who are just trying to stay abreast of innovations, students or research assistants who are seeking ways to make personal contributions, pre-tenure faculty, established senior researchers, and so on. If CiteSeer offers information about the seniority or reputation of a publication's author (based on data about other work by the same author), users might develop a richer awareness of who is playing what role in a project, and thus might be able to respond in a developmentally appropriate fashion. For instance, in the face of a problematic research result, a relatively junior research might receive only modest criticism and considerably more constructive advice than a senior researcher who "should know better".

Human development can happen at the level of individuals and groups. Scientists within a field often come together to assess their cumulative contributions and to consider how to collectively mould their efforts in the future ("Where should our field be in the next ten years?"). A service like CiteSeer can amalgamate contributions within a field by visualizing temporal trends through indices such as the impact factor of primary journals in that field, cross-citations with other disciplines, and so forth. Such trends could help scientists to evaluate their intellectual credential and assess the impact of their on other fields.

Like our earlier discussions of CiteSeer enhancements, the positive design ideas presented in this section are aimed at capturing and presenting back to scientists a view of the collaborative process that is already implicit in their publication-related activities. Writing, publishing, and responding to scientific papers is a normal – and for many a welcome – cost of developing as a researcher. Our design proposals acknowledge this practice, but at the same time offering a more expansive view of the publication process, creating benefits for awareness that go beyond the self-evaluation that now occurs.

7.2. Externalizing reflections about learning

Earlier we described how the use of real world case studies supports vicarious experience of a CoP's concepts and methods, helping students to emulate the techniques, languages, and the methods of an existing CoP. But learning *about* the practices and values of a CoP is just one step in people's professional development – they must be able also to apply these practices to their own work. In the context of usability engineering education, this means that students should apply their newly-acquired understandings on their class projects.

A challenge in creating authentic group project experiences for student in usability engineering is the artificial time constraint of a university course: groups must form, cohere, develop their shared understanding of concepts and methods, and apply this knowledge to their projects, all in a period of only a few months. To meet these life cycle challenges while also enhancing the learning benefits of the project, we have been exploring an extension of the collaborative case browser used to analyze and reflect on the real world cases, such that it can also be used to formulate and pursue class projects. The students gather and analyze requirements, design and prototype interactive activities at increasing levels of detail, and do usability studies to evaluate their ideas; the work products are documented in a collaborative case browser that is organized with the same high-level structure as the real world cases that the students have been analyzing and debating (Xiao et al., 2008) as in Fig. 5. As for the authentic cases, this browser includes support for collaborative reflection about the different phases of the project.

Undergraduate students are *not* usability professionals, but in some ways they are like individuals who are just beginning careers as usability analysts, or established professionals who shift their work to unfamiliar problem domains. The process of documenting their group projects as an instance of the same information structure used to organize the real world usability engineering cases, encourages the students reflect on their own practices while working on the project. They are given a rubric for comparing their group's activity with that of the real projects in the case library. In this sense, students who take the usability engineering course to prepare for a career can be seen as members of a learning community aimed at internalizing usability engineering practices. By sharing their own projects as case studies, they have the opportunity to develop analytical, critical thinking, and evaluation skills on their ongoing projects and thus grow their understanding of usability engineering as a profession.

Clearly the process of critical thinking and shared reflection is not without cost. In other courses where such techniques are being used, some students "push back", claiming that they already know how to do this kind of thinking, and that they do not need to write it down in a shared space; others have a more personal concern about being evaluated for the quality of the ideas they contribute (Xiao, 2008). But under the lens of positive design, we are seeking to convert these collaboration costs into enhanced opportunities for human development, as the students better understand how their own ideas are contributing to their group's success, and at the same time that they are taking their initial steps into the discipline of usability engineering.

8. Discussion: designing for awareness with a positive lens

Design-as-problem solving and design-as-possibility are both valid and useful perspectives, but they are distinct; they entail different concepts, representations, activities, and values.

Design-as-problem solving leads us to characterize a problem state specifying what is wrong or needs solving. It leads us to characterize possible moves or operators that could transform the initial problem state. And it leads us to characterize a set of criteria defining a goal state, the sets of states into which we would like to transform the original problem state. There are many ways to conceptualize problem states, moves/operators, and goal states. Newell and Simon (1972) inaugurated a tradition that treats problem states as symbols transformed by production rules. Today, this is close to an establishment view. The body of work addressing problems entrained by collaborative technology is a significant case in point.

Design-as-possibility starts from a vision of what might be, but is not (yet). A vision is a holistic glimpse of a better reality that is fleshed out with hopes and dreams. Visions are intended to reflect personal and collective values, to inspire action and commitment, to challenge assumptions, and to provide an optimistic prognosis. Examples of this type of design are legendary. The Dynabook concept developed at Xerox PARC in the 1970s was not intended to solve any manifest problem from that era. Rather it provided an alternative view of what computing could be about and what it could be used for. Information technology is brimming with such designs: Memex, the Alto, iPod, and so on.

In this paper, we have illustrated a programme of positive design research into the construct of activity awareness, making reference to three design cases. Activity awareness provides a rich canvas for investigating the positive lens view of design. We showed how mediated interactions provide new affordances in establishing and sustaining practices for common ground, communities of practice, social capital and human development. Our arguments are summarized in Table 3 as a set of eight strategies for positive design, described in Sections 4–7.

These examples illustrate two distinct value patterns of positive design. The first directly elaborates the proposal of Hollan and Stornetta (1992) that designers and design researchers should focus on understanding the new affordances of online media, and on leveraging these affordances to enhance activities in novel ways, *rather than* focusing on remediation for ways that online activities fail to reproduce real world activities. For example, in Section 4.2 (row 2 in Table 3) we described how dynamically aggregating patterns of knowledge sharing in CiteSeer could provide a new resource recognizing common ground by reminding scientists of their own social-professional ties. In Section 6.1 (row 5 in Table 3) we described how visualizing implicit exchange networks of keywords, queries, citations, and other scholarly transactions could enhance the formation of social capital among scientists. Like the Dynabook and the iPod, these examples are not mitigating deficits, but are envisioning new ways of enhancing experience.

We argued further that there is a second value pattern, that activity awareness can be supported by tools and interactions that require *effort* of participants, effort which nonetheless can be experienced as investment in group endeavor, and not merely seen as a cost or penalty of engaging in mediated interactions. For example, in Section 5.2 (row 4 in Table 3) we described how regional emergency planners might enhance their own activity awareness through creating digital artifacts (map annotations, timelines, role-based summaries) that reify planning practices as an artifact for subsequent analysis and reuse (e.g., in training). In Section 7.2 (row 8 in Table 3) we described how collaborative learning could be enhanced by externalizing the rationales and analysis of individual students to create richer learning objects for group reflection. In examples like these, awareness is achieved through explicit work, but that effort provides immediate value by attributing member contributions and engaging the group by structuring its own diverse knowledge as a resource.

This latter pattern seems especially interesting from the standpoint of future research directions. It has often been assumed that mediated interactions must be as simple as possible in order to facilitate human learning and performance (Card, Moran, & Newell, 1983). The very argument that FTF interaction constitutes a gold standard, and that mediated collaboration should be analyzed with respect to various ways awareness is diminished and coordination obstructed by mediation largely derives from this "least effort" perspective (Olson & Olson, 2000). Indeed, the pervasive assumption that human effort is always a deficit that must be minimized may explain why awareness research has focused so disproportionately on synchronous awareness issues (social/presence awareness, workspace/action awareness, gaze-deixis awareness, situation awareness), and so little on asynchronous awareness. A challenge to further research is to more generally characterize the class of circumstances in which additional effort can be experienced as investment in collaboration.

Table 3
Example design strategies that support activity awareness in ways beyond what is available in FTF collaborative practices.

Facet of activity awareness	Design strategy	Examples	How it illustrates positive design
Common ground	Integrated private and shared representations that are task-based	Collaborative maps for emergency planning, with both role-based and shared views	Emergency planning can occur throughout the year 24/7; planners are reminded of their specific roles and responsibilities by the structure of the map views (which enhances sharing)
	Aggregating and visualizing patterns of knowledge sharing	Scientific publication bookmarking, activity-based notification systems	Continuous pattern mining dynamically constructs and presents a scientist's community, suggesting new resources for sense making
Community of practice	Shared simulations of expert-level experiences	Role-based reflection and group analysis of usability engineering cases	Online case studies allow students to vicariously experience episodes of professional practice, which they can then emulate in class projects
	Organizational memory of problem-specific plans	Map-, time-, role-based views of recorded planning exercises	Digital artifacts created in the planning process reify the process itself (as opposed to just the outcome), helping to make the process an artifact that can be analyzed and refined for use in future planning and training
Social capital	Visualization of implicit exchange networks	Query- or citation-based networks to discover potential collaborators	Visualizing scientific publication interactions (citations, queries, keywords) surfaces social-professional groups and strengthen their internal affinity bonds
	Situationally-grounded resource requests	Attaching crisis concerns and resources to a shared map	Making decision rationale explicit helps members understand why plans are the way they are, helping members to support the plans more strongly
Human development	Emphasizing the value of member contributions	Citation visualizations that include impact factor of publications	Visualizing career trajectories and roles with respect to level and type of professional contributions at different stages serves as a resource for managing individual careers and for taking stock of entire fields
	Externalizing reasoning process in learning projects	Collaborative case editor for design projects and rationale	Digital case study repositories that support annotations and other collaborative analysis promote "reflective practice" among actors

An implication of our design argument is that mediated collaborations can be *more effective* in specific ways than FTF collaborations, particularly when those collaborations are significantly complex or sustained. If this is true, then we should expect to see increasing use of collaboration technologies, such as those described in this paper, not only for fully mediated interactions (e.g., among physically remote partners), but for partially mediated interactions, that is, for interaction among partners who could work FTF, but will choose to use collaborative technologies in order to enhance facets of their own activity awareness. This is an interesting prediction, since it exactly contradicts not only the premise but also the conclusion of a large body of theorizing about collaborative technologies (e.g., Olson & Olson, 2000). Of course, it remains an open question how long the development and adoption of such collaborative technologies might take, but perhaps we already have seen the beginnings of such transformations, in practices such as sending email to the person in the next office or posting to a blog for one's immediate family.

Our view is that design may succeed best when the two faces of design—design-as-problem and design-as-possibility—are engaged together and converge. But how can that happen? How can a holistic glimpse of a rich future be integrated with a punch list of annoying misconceptions and errors? In other writing, we have suggested that the two can be integrated in envisionment scenarios, narrative descriptions of situated human activity and experience (Carroll, 2000). Casting a problem statement as a scenario implicitly motivates a more integrative problem analysis relative to a traditional requirements list. Conversely, casting a vision of possibilities as a scenario motivates more disciplined analysis of just how new technology might be used, by whom, and for what. Indeed, the three designs discussed above were all initially developed through scenario analysis.

9. Conclusions

The work of design is the work of envisioning and creating the future. Doing this work necessarily involves a critical deconstruction of the world-as-it-is, and the identification of problems to solve. But design cannot have *only* this close-in, tactical focus on ameliorating current problems and managing immediate consequences. It must also focus a bit higher, look further ahead, and identify new possibilities for action and experience, in some cases possibilities substantially disjoint with the world-as-it-is.

In our research on support for collaborative group work, on issues that arise in complex and sustained collaborations, and on collaborative technologies that relax the distinction between synchronous and asynchronous coordination, we are trying to address this challenge. In this paper, we characterized the construct of activity awareness – a group's awareness and regulation of its own collective activity through protocols for establishing and maintaining common ground, communities of practice, social capital, and human development. We argued that activity awareness is critical in significant joint endeavor, and that accordingly, it is a key requirement for tools and systems to support mediated collaboration.

We characterized awareness as an opportunity area for positive design: Awareness support in collaboration technology has focused on relatively simple and ephemeral aspects of awareness, and the central design challenge has typically been construed as one of mitigating awareness deficits relative to direct FTF human interaction. With a series of design examples drawn from a varied set of collaboration domains, we demonstrated the possibility of awareness support *beyond being aware* in the sense of direct FTF interaction. We framed eight strategies for positive design support for activity awareness.

Many challenges remain. Our results here are an existence demonstration, a proof of concept, but they need to be more widely implemented and deployed, and more extensively investigated and evaluated. More importantly, in our view, other designers of collaborative technologies must begin to consider the possibility that they can and ought to do more than mitigate the collaborative deficits of mediated collaboration. We must more systematically and pervasively integrate the visions and possibilities of positive design into all CSCW design. We believe that incorporating positive design into standard conceptions and methods for framing design requirements and objectives is a key to the conundrum of how to get from what Ackoff (1979) called "managing messes" to effective and creative systems design.

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