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COLLABORATIVE DESIGN RATIONALE AND SOCIAL CREATIVITY IN CULTURES OF PARTICIPATION

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Abstract: *The rise in social computing has facilitated a shift from consumer cultures, focused on producing finished media to be consumed passively, to cultures of participation, where people can access the means to participate actively in personally meaningful problems. These developments represent unique and fundamental opportunities and challenges for rethinking and reinventing design rationale and creativity, as people acclimate to taking part in computer-mediated conversations of issues and their solutions. Grounded in our long-term research exploring these topics, this paper articulates arguments, describes and discusses conceptual frameworks and system developments (in the context of three case studies), and provides evidence that design rationale and creativity need not be at odds with each other. Coordinating and integrating collective design rationale and social creatively provide new synergies and opportunities, particularly amid complex, open-ended, and ill-defined design problems requiring contributions and collaboration of multiple stakeholders supported by socio-technical environments in cultures of participation.*

Keywords: *collaborative design, creativity, cultures of participation, design, design exploration, design rationale, domain-oriented design environments, Envisionment and Discovery Collaboratory, incremental formalization, metadesign, science of design, social creativity, spatial hypertext, Visual Knowledge Builder.*

INTRODUCTION

Most of the pressing and important design problems of today's world are systemic problems that make collaboration supported by new technologies not a luxury but a necessity. These systemic problems—including the design of policies to address environmental degradation, economic disparity, and the disappearance of local cultures in the age of globalization, to name

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a few—are complex, open-ended, and ill-defined (Rittel & Webber, 1984; Simon, 1996), requiring

- contributions of many minds, particularly from the people who "own" problems and are directly affected by them;
- the integration of problem framing and problem solving, where the understanding of the problem co-evolves with the activity of designing a solution (Schön, 1983);
- communication and collaboration among people from different disciplines and educational levels (Clark & Brennan, 1991); and
- intelligent use of technologies and resources that support collective knowledge construction where multiple people contribute to a shared knowledge representation (Arias, Eden, Fischer, Gorman, & Scharff, 2001).

These problems need contributions from people with a wide range of experiences and perspectives, including stakeholders representing all those affected by the design results. The problems also often evolve over time, providing unique new challenges for design rationale and creativity research.

In this paper we first describe our understanding of the cultures of participation that are becoming more common on the Web, where volunteers share design activities with professional designers. We then discuss design and design rationale, and use our past work to articulate some of the challenges of supporting collaborative design to be addressed by the following sections. This is followed by arguments for the social nature of creativity and discussion on how metadesign and the seeding, evolutionary growth, reseeding model support collaborative design rationale and social creativity. Then three case studies are presented, describing (a) the Envisionment and Discovery Collaboratory, a long-term research platform exploring conceptual frameworks for social creativity and democratizing design in the context of complex design problems; (b) the Design Exploration Builder and Analyzer; and (c) the Visual Knowledge Builder that illustrates incremental formalization. These demonstrate how the more general ideas were pursued in specific contexts. We end the paper by presenting implications and conclusions.

CULTURES OF PARTICIPATION

While initially a space where anyone could publish almost anything, the World Wide Web in its first decade led to a separation between designers and consumers for many forms of content. New technological developments, such as Web 2.0 architectures and infrastructures (O'Reilly, 2006), have emerged to support a social or participatory Web, where people use comments, annotations, blogs, and so forth to converse with others about topics of interest. These developments are the foundations for a fundamental shift from consumer cultures, in which people passively consume finished goods produced by others, to cultures of participation, in which all people are provided with the means to participate actively in personally meaningful activities.

Consumer cultures go hand in hand with professionally dominated cultures characterized by a small number of producers and a large number of consumers. The traditional information cultures surrounding the systemic problems introduced above (e.g., policy design) are traditionally based on strong input filters (e.g., editorial boards deciding what gets published, low acceptance rates for conferences and journals), where relatively small information repositories are created. The advantage is the likelihood that the quality and trustworthiness of the accumulated information is high, and that relatively weak output filters are required. The disadvantages of this model are that it greatly limits that "all voices can be heard"; that most people are limited only to accessing existing information; and that potentially relevant information (which may be of great value not at a global level, but for the work of specific individuals) may not be incorporated into the information repository.

Cultures of participation can be characterized by weak input filters that allow users to become active contributors engaging in informed participation (Brown et al., 1994). Cultures of participation provide a framework to rethink design rationale and creativity from the following perspectives:

- by enabling users to innovate, they can develop exactly what they want, rather than relying on developers to act as their agents; this democratizes innovation by putting the owners of problems in charge (von Hippel, 2005);
- by breaking down many of the distinctions between designers and users through metadesign (i.e., designing tools so that they can be redesigned by the end users and designing tools for use by designers; Fischer & Giaccardi, 2006) many more voices can be heard and social creativity can be supported (Fischer et al., 2005);
- by decentralizing design (Benkler, 2006), the power of the long tail (Anderson, 2006) and the wisdom of crowds (Surowiecki, 2005) can be exploited.

We are exploring numerous themes in our efforts to understand, foster, and support cultures of participation with social computing, including

- Models of community (Fischer, 2001; Wenger, 1998*)*: how the shared knowledge and common ground necessary for effective communication are created to support mutual learning and collaborative problem solving;
- Distributed intelligence (Salomon, 1993): the idea that intelligence is not located in a single mind but is distributed among people and tools that work together, and emerges in the process of problem solving;
- Reflection: helping individuals and communities intelligently monitor, assess, and adapt their work through such processes as "reflection-in-action" and "reflection-on-action," where conscious evaluation of an action's effects occur during or after design (Schön, 1983);
- Sociotechnical design (Mumford, 2000): with emphasis on the evolutionary creation of effective learning and problem-solving environments made possible with new media and having interacting social and technical components; and
- Exploiting knowledge sources from the "Long Tail" (Anderson, 2006): engaging learners in self-directed learning activities about which they feel passionate.

DESIGN AND DESIGN RATIONALE

Design is a ubiquitous activity that is practiced in everyday life as well as in the workplace by professionals (Cross, 1984; Schön, 1983; Simon, 1996). It is not restricted to any specific discipline, such as art or architecture, but instead is a broad human activity that pursues the question of "how things ought to be," as compared to the natural sciences, which study "how things are" (Simon, 1996). It is a fundamental activity within all professions: Architects and urban planners design buildings and towns, educators design curricula and courses, people in the creative practices design new artifacts with new media, citizens from around the world contribute 3D models to be displayed in Google Earth, and software engineers design socio-technical environments for people with cognitive disabilities (Fischer, 2010).

Design problems can be framed in different ways and they have no unique answers. A core activity of design is not only problem solving but also continual problem finding and problem framing, the selection of a framework with which to discuss and/or model the problem (Rittel, 1984). It is a process of dealing with the kind of "messy situations" (Rittel & Webber, 1984) that are characterized by uncertainty, conflict, and uniqueness, and it can best be characterized by creativity, judgment, and dilemma handling, rather than by objective scientific methods.

Design rationale (or *argumentation*, which will be used as a synonym) represents and articulates the reasoning underlying the design process that explains, derives, and justifies design decisions. A complete account of the reasoning relevant to design decisions is

- not possible because some design decisions and the associated reasoning are made implicitly by construction and are not available to conscious thinking (e.g., decisions based on tacit knowledge). Some of the rationale must be reconstructed after design decisions have been made; and
- not desirable because many design issues are trivial; their resolution is obvious (Schön, 1983) to the competent designer, or the design issue is not very relevant to the overall quality of the designed artifact. Accounting for all reasoning is not desirable because it would divert too many resources from designing itself.

The promise of design rationale is achieved if it helps designers

- to improve their own work;
- to cooperate with other people holding stakes in the design;
- to understand existing artifacts (i.e., to communicate with past designers); and
- to trigger critical thought (i.e., writing an idea down allows designers to make the transition from simply creating that idea to reflecting about it).

Collaborative design is a necessity rather than a luxury because most important design problems are complex, requiring social creativity in which stakeholders from different disciplines must collaborate. Design rationale can serve as a memory aid not only to individuals but also to groups (Conklin & Begeman, 1988) by providing a forum for airing issues crucial for coordinating group activities. It is useful for triggering and focusing discussion among members of a project team. By making the processes of reasoning public, it extends the number of people who can participate in the critical reflection on decisions, thereby reducing the chances of missing important considerations.

Our Past Design Rationale Research

In an article titled "Making Argumentation Serve Design" (Fischer et al., 1996), we argued that construction is essential for design, for no design project can be completed until the construction is done. Based on Schön's (1983) work, we conceptualized design not primarily as a form of problem solving, information processing, or search, but as a kind of making and creating environments in which design knowledge and reasoning could be expressed in designers' transactions with materials, artifacts made, conditions under which they are made, and manner of making.

These ideas led to the development of a class of systems called *domain-oriented design environments* (DODEs; Fischer, 1994). A prominent example was JANUS, a DODE for kitchen design (see Figures 1 and 2).

The short messages the critics presented to designers did not reflect the complex reasoning behind the corresponding design issues. To overcome this shortcoming, we initially developed a static explanation component for the critic messages. The design of this component was based on the assumption that there is a "right" answer to a problem. However, the explanation component proved to be unable to account for the deliberative nature of design problems. To enrich the "back-talk" of the situation, argumentation about issues raised by critics must be supported and argumentation must be integrated into the context of construction.

The core ideas relevant for design rationale and creativity that we developed and analyzed in the context of our DODEs research were

- to make argumentation serve design and to support reflection-in-action and reflection-on-action (Schön, 1983), we had to link action (construction; see Figure 1) with argumentation (reflection; see Figure 2); this was achieved with critiquing systems (see "messages" pane in Figure 1; Fischer et al., 1998);

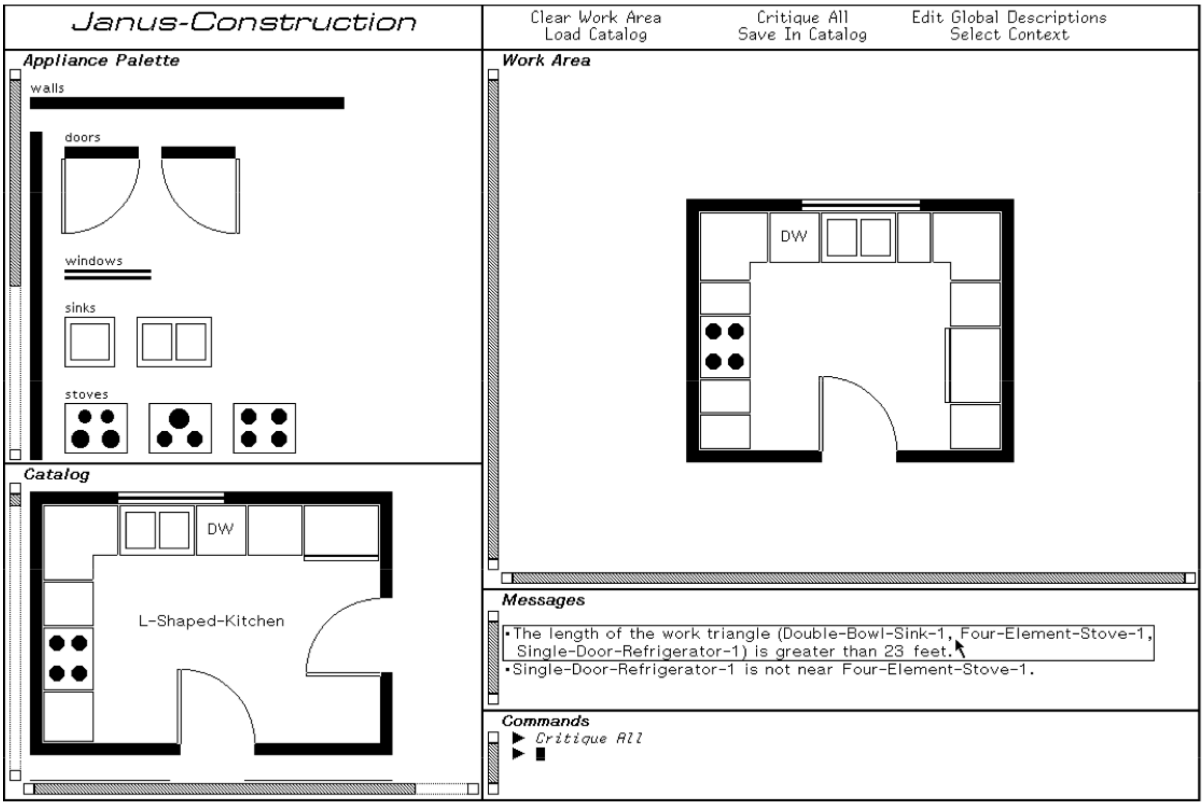
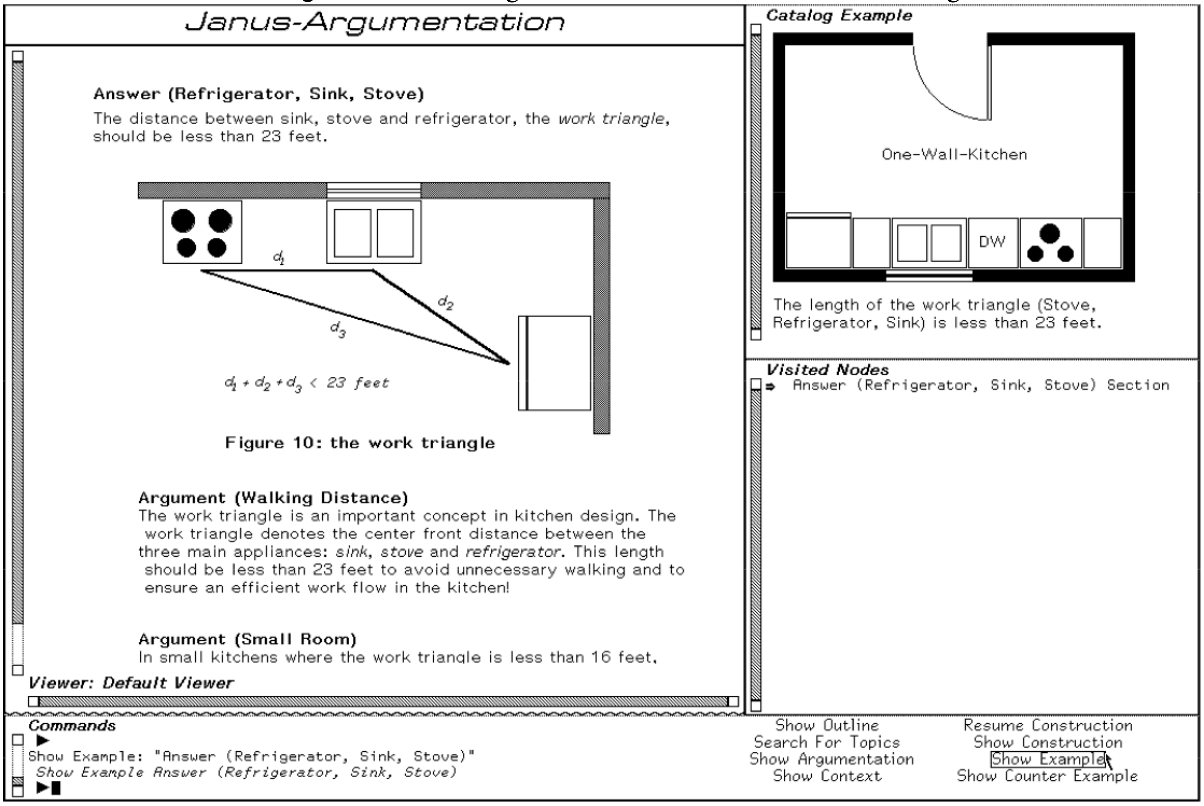


Figure 1. JANUS-Construction: A DODE for kitchen design.

Figure 2. JANUS-Argumentation: A DODE for kitchen design.



- to avoid designers being taken off-task with elaborate design rationale recording activities, incremental formalization (Shipman, 1993; Shipman & McCall, 1994; see more below) was developed as an important technique to allow designers to leave reminders in the environments to be developed at later points of time;
- to contextualize/illustrate argumentation with concrete, specific examples, the Argumentation Illustrator was employed (see "Catalog Example" pane in Figure 2).

We explored and supported the following issues for effective documentation and use of design rationale:

- a rationale representation scheme was used to organize information according to its relevance to the task at hand;
- argumentative and constructive design activities were explicitly linked by integrated design environments; and
- the reusability of the argumentation was supported.

Collaborative Design

Design projects may take place over many years, with initial design followed by extended periods of evolution and redesign. In this sense, design artifacts typically are not designed once and for all, but instead they evolve over long periods of time (Fischer et al., 1992). In such long-term design processes, designers may extend or modify artifacts designed by people they actually have never met.

In extended and distributed design projects, specialists from many different domains must coordinate their efforts despite large separations of time and distance. In such projects, long-term collaboration is crucial for success, yet it is difficult to achieve. Complexity arises from the need to synthesize different perspectives (Fischer, 2001), exploit conceptual collisions between concepts and ideas coming from different disciplines, manage large amounts of information potentially relevant to a design task, and understand the design decisions that have determined the long-term evolution of a designed artifact.

An important objective to support collaborative design is the externalization of tacit knowledge (Polanyi, 1966). Externalizations (Bruner, 1996) can support creativity in the following ways:

- They cause us to move from a vague mental conceptualization of an idea to a more concrete representation of it, which creates situational back-talk (Schön, 1983), making thoughts and intentions more accessible to reflection;
- They produce a record and rationale of our mental efforts, one that is outside us rather than vaguely in memory;
- They provide a means for others to interact with, react to, negotiate around, and build upon an idea; and
- They are critically important for social interactions because sometimes a group has no "head" leading to the artifact becoming the focus of social activity (Reeves, 1993).

CREATIVITY

The Social Nature of Creativity

The power of the unaided individual mind is highly overrated (John-Steiner, 2000; Salomon, 1993). Although creative individuals (Gardner, 1993; Sternberg, 1988) are often thought of as working in isolation, much of our intelligence and creativity results from interaction and collaboration with other individuals (Csikszentmihalyi, 1996). Creative activity grows out of the relationship between individuals and their work, as well as from the interactions between individuals. In other words, creativity does not only happen inside people's heads, but in the interaction between a person's thoughts and a sociocultural context (Engeström, 2001). Situations that support social creativity need to be sufficiently open-ended and complex so that users will encounter *breakdowns* (Schön, 1983). As any professional designer knows, breakdowns—although at times costly and painful—offer unique opportunities for reflection and learning.

Social creativity includes the exploration of computer media and technologies to help people work together. It is relevant to design because collaboration plays an increasingly significant role in design projects that require expertise in a wide range of domains. Software design projects, for example, typically involve designers, programmers, human–computer interaction specialists, marketing people, and end-user participants (Greenbaum & Kyng, 1991). Information technologies have reached a level of sophistication, maturity, cost-effectiveness, and distribution so they are not restricted only to enhancing productivity; they also open up new, creative possibilities (Mitchell, Inouye, Blumenthal, & the National Research Council, 2003).

Despite the rhetoric of collaboration, however, the prevailing perspective in the US on design work advocates within universities, schools, offices, and communities a culture in which people need to distinguish themselves as individuals (Bennis & Biederman, 1997). As already mentioned, collaboration in today's world is not a luxury but a necessity. We need not only reflective practitioners (Schön, 1983), but reflective communities. We need to understand how individual and social creativity (Fischer et al., 2005) interact with each other, and how we can exploit distribution and diversity in design teams, communities, and tools that support reflective communities.

Multiple Distances in Social Creativity

The social nature of creativity establishes the fundamental objective for design rationale that is constructed collaboratively. The goal seeks to support collaboration and integration of many minds and many artifacts across multiple distances: spatial, temporal, and conceptual.

Spatial Distances. Bringing spatially distributed people together by supporting computer-mediated communication allows the shift that shared concerns rather than shared location become the prominent defining feature of a group of people interacting with each other. It further allows more people to be included, thus exploiting local knowledge. These opportunities have been employed successfully by the open source communities (Scharff, 2002). Transcending the barrier of spatial distribution is of particular importance in locally sparse populations, enabling a critical mass of interest in a topic to form when it otherwise would not.

Temporal Distances. A design strategy for making creative contributions is to master as thoroughly as possible what is already known in a domain. The ultimate goal is to transcend conventions, not to succumb to them (dePaula & Fischer, 2004). Design processes often take place over many years, with initial design followed by extended periods of evolution and redesign. Design artifacts and systems (such as reuse environments; Ye & Fischer, 2002) are not designed once and for all, but instead evolve over long periods of time (Dawkins, 1987).

Much of the work in ongoing design projects is done as redesign and evolution, and often the people doing this work were not members of the original design team. To be able to do this work well, or sometimes at all, requires that these people collaborate with the original designers of the artifact, through artifact or media support for indirect collaboration. In ongoing projects, long-term collaboration is crucial for success, yet difficult to achieve. This difficulty is due in large part to individual designers' ignorance of how the decisions they make interact with decisions made by other designers. A large part of this, in turn, results from simply not knowing what has already been decided and why.

Long-term collaboration requires that present-day designers be aware of not only the rationale (Moran & Carroll, 1996) behind decisions that shaped the artifact, but also any information about possible alternatives that were considered but not implemented. This requires that the rationale behind decisions be recorded in the first place. A barrier to overcome is that designers are biased toward doing design, not toward putting extra effort into documentation. This creates an additional rationale–capture barrier for long-term design (Grudin, 1987).

In the context of long-term, indirect collaboration (Fischer et al., 1992), *incremental formalization,* where structure is added over time to content initially captured in a less structured form (Shipman, 1993), is an attempt to achieve two conflicting goals: (a) assuring that design rationale recording does not take too many cognitive resources away from the primary task to be done; and (b) assuring that the rationale is (at least partially) formalized so that computational support makes it easier to retrieve later when needed.

Conceptual Distances. Diversity is not only a constraint to deal with but also an opportunity to generate new ideas, new insights, and new environments (Basalla, 1988; Mitchell et al., 2003). The challenge is often not to reduce heterogeneity and specialization, but to support it, manage it, and integrate it by finding ways to build bridges between local knowledge sources and by exploiting conceptual collisions and breakdowns as sources for innovation. Our own research efforts have focused on supporting diversity based on the conceptual gap between stakeholders from different practices (conceptual distances between different domains). Rather than being focused on homogeneous communities of practice (CoPs; Wenger, 1998), we have been particularly interested in heterogeneous communities of interest (CoIs; Fischer, 2001) that bring together stakeholders from different CoPs to solve a particular (design) problem of common concern. CoIs can be thought of as "communities-of-communities" (Brown & Duguid, 2000) or communities of representatives of communities. Fundamental challenges facing CoIs are found in building a shared understanding (Resnick et al., 1991) of the task-at-hand, which often does not exist at the beginning but evolves incrementally and collaboratively and emerges in people's minds and in external artifacts. Members of CoIs must learn to communicate with and learn from others (Engeström, 2001) who have different perspectives and perhaps different vocabularies to describe their ideas, and to establish common ground (Clark & Brennan, 1991).

Boundaries as they exist in CoIs are the locus of the production of new knowledge and therefore an important source of creativity. They are where the unexpected can be expected, where innovative and unorthodox solutions are found, where serendipity is likely, and where old ideas find new life. The diversity of CoIs may cause difficulties, but it also may provide unique opportunities for knowledge creation and sharing. Boundary objects (Bowker & Star, 2000; Star, 1989) are objects that serve to communicate and coordinate the perspectives of various constituencies. They serve multiple constituencies in situations where each constituency has only partial knowledge and partial control over the interpretation of the object. Boundary objects perform a brokering role involving translation, coordination, and alignment among the perspectives of different CoPs coming together in a CoI. For example, a building floor plan may act as a boundary object between the constituents concerned with plumbing and those concerned with electrical issues in the design.

COLLABORATIVE DESIGN RATIONALE AND SOCIAL CREATIVITY IN CULTURES OF PARTICIPATION

Creativity and innovation are being democratized (von Hippel, 2005): Users of products and services are increasingly able to create and innovate for themselves (in the sense of psychological creativity, i.e., new to the person, rather than historical creativity, i.e., new to the world; Boden, 1991). Democratizing design is necessary because users' needs are highly heterogeneous in many fields and therefore cannot be anticipated by designers; users' expertise and talent also is widely distributed. Although the existence and availability of tools are necessary, they are not sufficient to support social creativity and democratizing design. Access to these environments is a first step, but we need to create sociotechnical environments (Mumford, 2000) that allow people to acquire the technical knowledge and social skills necessary to use them and adapt them to their needs.

In CoPs, collaboratively constructed design rationale can bring social creativity alive by

- allowing participating stakeholders to express themselves by combining different perspectives and generating new understandings, thus avoiding being entrenched in "group think" (Janis, 1972);
- making all voices heard and exploiting the symmetry of ignorance (Fischer, 2000) as a source for new insights rather than as limitations; these two concepts are specifically important in dealing with complex, systemic problems that require more knowledge than any single person possesses (e.g., in software design, domain experts understand the practice and system designers know the technology);
- supporting distances and diversity in multiple dimensions (Fischer, 2005) and creating boundary objects understandable across different domains (Star, 1989) will allow users to develop common ground and shared understanding.

We have developed metadesign and the seeding, evolutionary growth, reseeding model as frameworks to foster and support CoPs by providing all people with the means to participate actively in personally meaningful problems.

Metadesign: Creating Opportunities for Creativity

To bring social creativity alive with collaboratively constructed design rationale, media and environments can be supported by metadesign. Metadesign (Fischer & Giaccardi, 2006) characterizes objectives, techniques, and processes that allow users to act as designers and be creative. The need for metadesign is founded on the observation that design requires open systems that users can modify and evolve. Because problems cannot be completely anticipated at design time, when the system is developed, users will discover mismatches between their problems and the support that a system provides during use time. These mismatches will lead to breakdowns that serve as potential sources for new insights, new knowledge, and new understanding. Metadesign advocates a shift in focus from finished products or complete solutions to conditions for users to fix mismatches when they are encountered during use.

Metadesign supports informed participation (Brown & Duguid, 2000), a form of collaborative design in which participants from all walks of life (not just skilled computer professionals) transcend the information given to incrementally acquire ownership in problems and to contribute actively to their solutions. It addresses the challenges associated with open-ended and multidisciplinary design problems. These problems, involving a combination of social and technological issues, do not have "right" answers at the start, and the knowledge to understand and resolve them changes rapidly. Successful coping with informed participation requires social changes as well as new design rationale that provides the opportunity and resources for social debate and discussion rather than merely delivering predigested information to users.

The Seeding, Evolutionary Growth, and Reseeding (SER) Model

The SER model (Fischer et al., 2001) characterizes the lifecycle of large evolving systems and information repositories. The lifecycle starts with a seed that is developed by a design team composed of domain experts and software designers and provided to domain users. At this point the system or repository alternates between periods of activity and unplanned evolutions made by domain users, and periods of deliberate (re)structuring and enhancement by the design team. The SER model requires the support of users as designers in their own right, rather than restricting them to only passive consumer roles. It provides a framework that supports social creativity through supporting individual creativity. Users of a seed are empowered to act not just as passive consumers, but also as informed participants who can express and share their creative ideas. System design methodologies of the past were focused on building complex information systems as "complete" artifacts through the large efforts of a small number of people. Conversely, instead of attempting to build complete and closed systems, the SER model advocates building seeds that can be evolved over time through the small contributions of a large number of people. The SER model provides a framework to analyze and support environments that are evolved by CoPs.

Many design activities can be characterized by the SER model. Even before the introduction of Wikipedia and other Web 2.0 applications, activities ranging from the design of operating systems (e.g., UNIX), document preparation systems (e.g., MS Word), and the development of university courses (dePaula et al., 2001) involved alternating phases of the gradual introduction of new features or ideas and phases of reorganization to enable further enhancement.

CASE STUDIES

This section describes three case studies. They are based on the experiences with our previous work and informed by the frameworks discussed in the previous sections.

The Envisionment and Discovery Laboratory (EDC)

The EDC (Arias et al., 2001) is a long-term research platform exploring conceptual frameworks for social creativity and democratizing design in the context of complex design problems. It brings together participants from various backgrounds to frame and solve ill-defined, open-ended design problems. The EDC provides contextualized support for reflection-in-action (Schön, 1983) within collaborative design activities (see Figure 3).

In many cases, the knowledge to understand, frame, and solve complex design problems does not already exist (Engeström, 2001), but is constructed and evolves during the solution process—an ideal environment to study social creativity. The EDC represents a sociotechnical environment incorporating a number of technologies, including tabletop computing, the integration of physical and computational components supporting new interaction techniques, and an open architecture supporting metadesign.

Our work with the EDC has demonstrated that

- more creative solutions to urban planning problems can emerge from the collective interactions with the environment by heterogeneous CoIs than homogeneous CoPs (Wenger, 1998): The EDC avoids group think (Janis, 1972) by supporting open representations that allow for deeper understanding, experimentation, and possibly refutation;
- participants are more readily engaged if they perceive the design activities as personally meaningful by associating a purpose with their involvement (Brown et al., 1994): A critical element in the EDC design is the support for participation by individuals whose valuable perspectives are related to their embedded experiences (e.g., neighborhood residents) rather than on any domain expertise;
- participants must be able to naturally express what they want to say (Myers et al., 2006): The EDC employs the use of physical objects and supports parallel interaction capabilities and sketching to create inviting and natural interactions; the interaction mechanisms must allow participants to record design rationale with a reasonable effort: Figure 4 shows one system component that we developed to integrate design rationale into the EDC.

Figure 3. The EDC showing action space (horizontal board), reflection space (vertical board) and multiple stakeholders interacting with computationally enhanced physical objects.

- visualization of conflicting actions and decisions lead to lively discussion among participants and helps them reach consensus or explore further alternatives (Rittel, 1984); and
- the representations of decisions and their consequences should be easily shared with other users so they can reflect upon others' decisions (Ye et al., 2004).

Figure 5 illustrates two aspects:

- *Visualization support:* The EDC allows stakeholders to sketch new buildings, associate a height with them, and analyze their impact on the surroundings (e.g., Do they block a neighbor's view of the mountains?). An integration with Google Earth is used to create the visualization shown from different locations.
- *Incremental formalization:* The two panes illustrate how we support incremental refinement and formalization in this context. The left pane shows very crude sketches of new buildings created with a minimal effort to explore height limitations. The right pane shows versions based on the crude images that are refined to resemble more closely the buildings that will be eventually constructed by taking advantage of existing 3D models from Google's 3D Warehouse.[1] The gradual progression from rough concepts of a design to more detailed designs (e.g., the 3D model) is an example of incremental refinement and formalization.

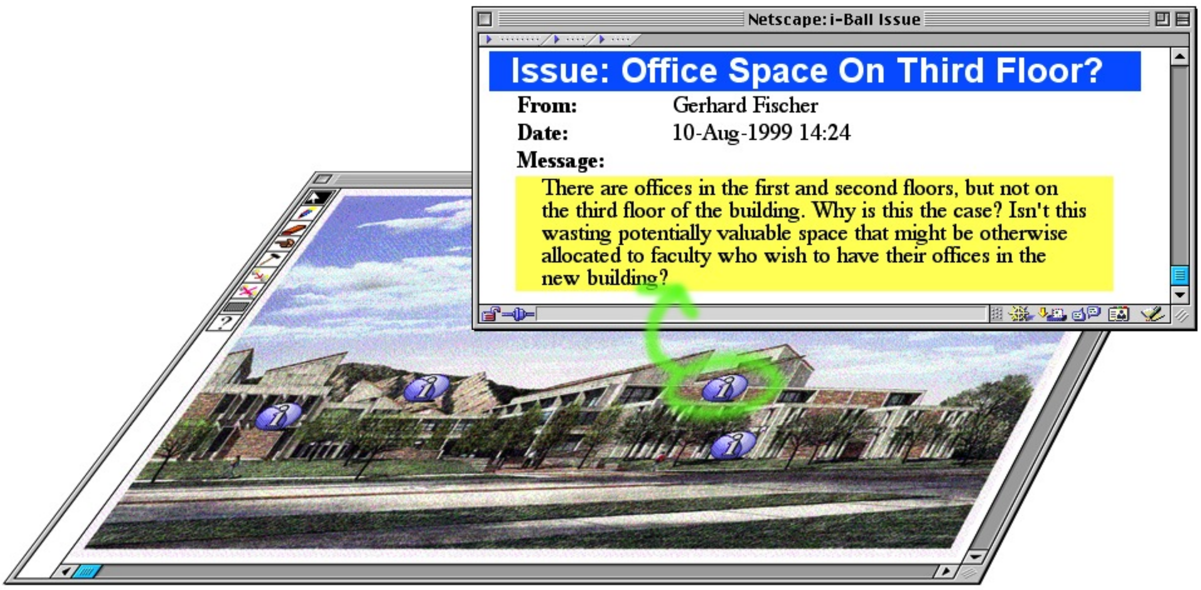


Figure 4. The association of design rationale with buildings in the EDC.
The answer to the question shown in the Figure is that the architects wanted to allow in more natural light from the streets between the buildings and therefore designed the buildings so that higher floors were set back in comparison to lower floors.

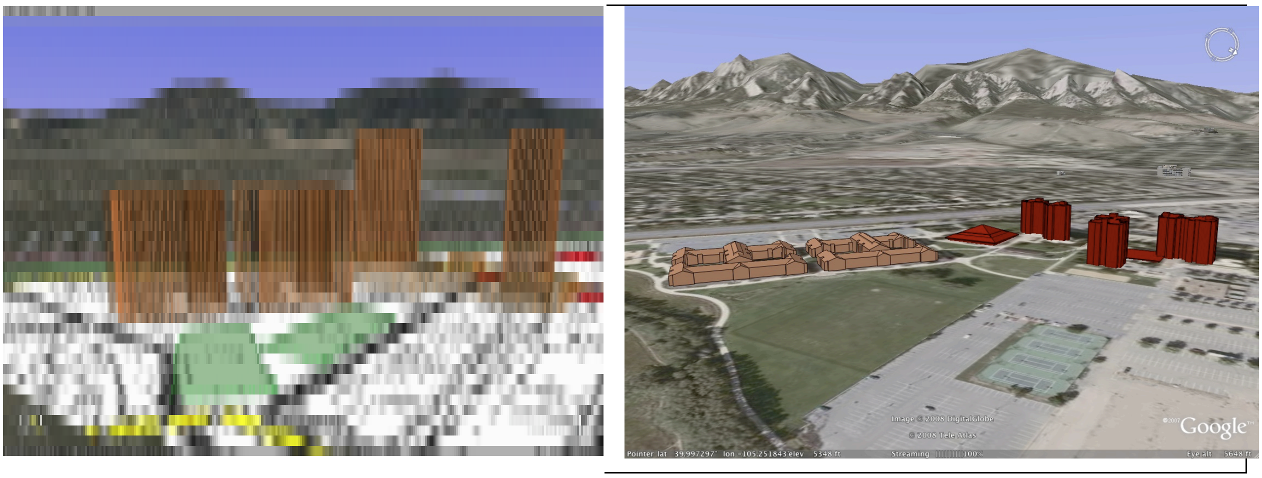


Figure 5. Visualization and incremental formalization in the EDC.

Increasing Participation Through Design Exploration

Design Exploration (DE) is a process formulated to collect and make use of creative input from a larger number of stakeholders than is traditionally included in design (Moore & Shipman, 2008). We explored this process in the context of interface design. DE democratizes design by asking stakeholders to generate partial designs, using the program DE Builder (a deliberately rough-hewn GUI builder) for the domain of widget-based interfaces. DE Builder supports the creation of windows and the layout of widgets on these windows. Additionally, each window and widget can include free-form text (annotations) explaining the graphic design. In this way, stakeholders can choose between visual and textual modes of expression based on individual preferences and the concepts in question. Annotations can combine description of the design choices with explanation for why those choices were made (i.e., rationale).

While the DE Builder attempts to minimize the effort for stakeholders to express design ideas, it potentially increases the effort required to make use of these ideas. Therefore, a second tool supports the DE process: The DE Analyzer provides an environment that aids interface designers in browsing and making sense of a collection of annotated partial designs. The DE Analyzer includes textual analysis of the annotations and text components of widgets and windows, as well as spatial analysis of the layout of widgets in windows. In Figure 6, the designer is examining the main window of an application for locating housing in a college town that was created by one of 75 undergraduates who created annotated partial designs in a study of the system. In this case, the designer can navigate to other designs based on similar terms and concepts, similar spatial structure, or by browsing or searching the vocabulary of terms used by the students.

Studies of the effectiveness of the DE process and tools have occurred for both the collection phase and the analysis phase (Moore, 2007). In a study collecting annotated partial designs, we divided participants into three groups: those having only textual forms of expression or only visual forms of expression, and those having both forms of expression. This provided several insights regarding textual and visual design expression:

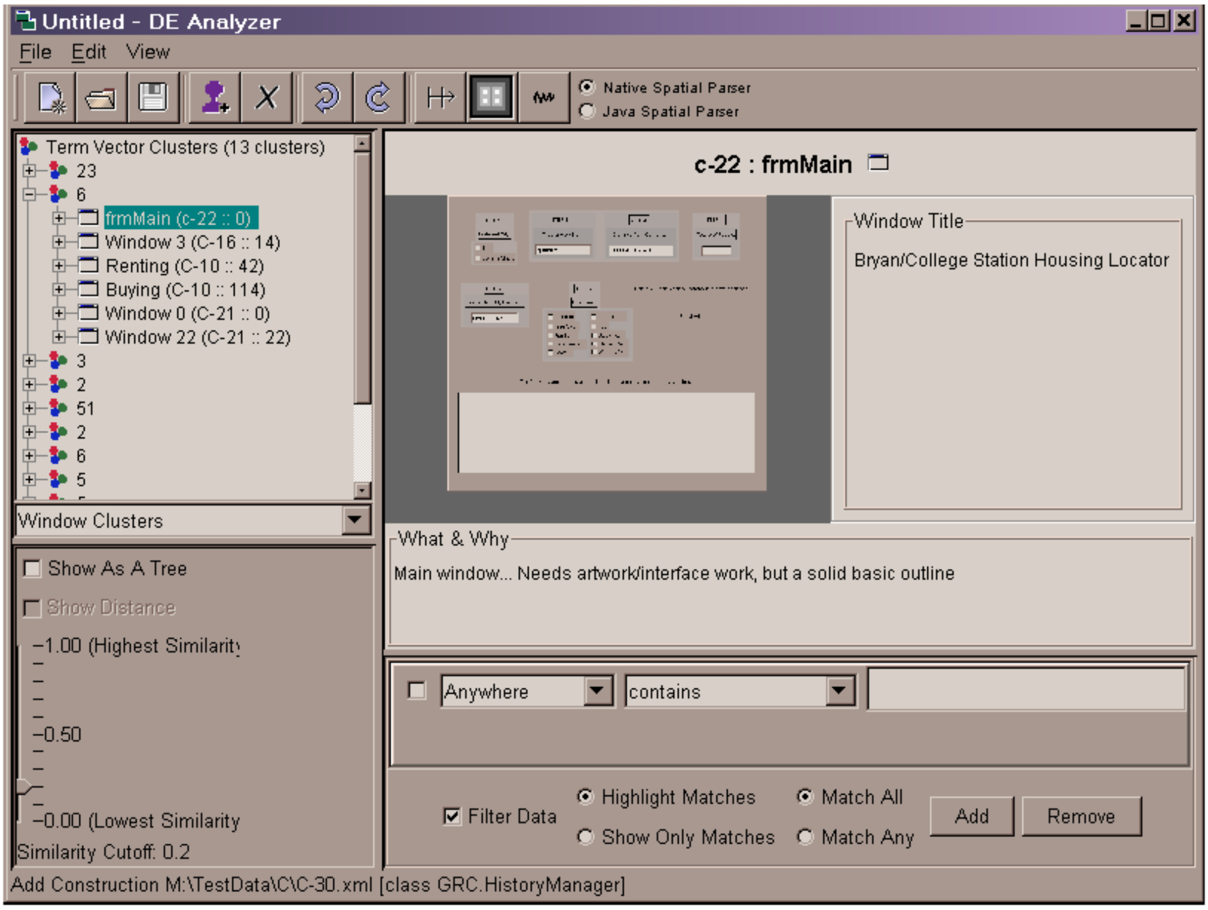


Figure 6. DE Analyzer showing reduced view of design and associated text.

- There are clear individual preferences for modes of expression when designing interfaces. Some stakeholders will work around the limitations of the system, for example, by generating window layouts in formatted text and using button or other widget text to explain the operation or reasoning behind a design.
- Visual expression motivated stakeholders. Stakeholders in the visual and both visual and textual conditions were more satisfied with their activity and spent longer times generating their feedback than did the stakeholders in the text only condition. In addition, the stakeholders in the visual and textual condition provided more text than the stakeholders in the textual condition.
- Providing tools that limit stakeholders to generating rough designs (e.g., no alignment and distribution options, no snap-to-grid, coloring, or shading options) was frustrating to some stakeholders. These few spent time trying to beautify designs rather than explain or expand the scope of their designs.

A study involving the use of the DE Analyzer pointed to a number of features and issues with interpreting collections of partial designs:

- Designers liked to navigate by vocabulary. Finding all the interface windows involving *apartments* or *condos* aided in locating alternative design ideas around single or related concepts. Designers commented that the ability to navigate through a variety of means meant they could follow different lines of reasoning or investigation while exploring the collection.

- Designers asked to locate design concepts from a collection of annotated partial designs generated a similar number of design concepts as those designing without access to partial designs (e.g., brainstorming). The negative interpretation of this result is that the number of concepts was not greater, although many more stakeholders were represented by the overall design process. The positive interpretation is that the two sets of designers had the same time limit for their work. Thus, those browsing the collection of partial designs generated a similar number of design concepts while using a complex system to browse a large information space and giving voice to the design ideas of a number of stakeholders.

The DE process was meant as an intermediary between participatory design, where a few stakeholders provide input through rich communication channels, and surveys and questionnaires, where many stakeholders provide input through less expressive forms. It democratizes design in the sense that end users create and explain potential designs. Moving ahead, it is natural to support design groups and to include mechanisms for stakeholders to comment on and share aspects of their annotated partial designs.

Supporting Incremental Formalization in Spatial Hypertext

The need for incremental formalization became evident in early efforts to merge hypertext systems with knowledge representations systems. Both hypertext and frame-based or object-based knowledge representations require expression in nodes that are connected via associations. We, and others, saw this similarity to be an opportunity to integrate discussions about domain activities with knowledge engineering by domain experts. What became clear was that systems integrating these activities were fine for authoring human-readable and navigable content but did not result in the creation of formal knowledge structures required by knowledge representation engines (Shipman & Marshall, 1999).

An analysis of the representations shows that the node and association representations were not as similar as originally thought. In hypertexts, the internal representation of a node is in a natural form of communication (natural language, image, video, etc.) while knowledge representations require the internal representation of nodes to be structured in a form interpretable by the computer (e.g., attributes with values and methods). Associations in hypertexts are generally navigational links although some hypertext systems, including design rationale systems, allow or force the assignment of a type to the link. These associations imply a relationship exists between the nodes but say little about the semantics of that relationship or its effect on the semantics of the nodes. On the other hand, associations in knowledge representations encode specific semantic relationships that can be acted upon by production rules or other forms of automatic interpretation.

Users of these systems created navigational links between authored chunks of information. They were less willing to assign specific semantics to the link. More generally, systems that included both natural and formal modes of communication found unexpected use of natural forms of communication in order to avoid use of the formal modes of communication. One such example comes from the use of Aquanet shown in Figure 7. Aquanet, developed by Catherine Marshall and colleagues at Xerox PARC (Marshall et al., 1991), included the ability to define relation types and constraints on the object types that could fill roles in relations. It also provided for relatively freeform visual expression through modifications to object shape, color, and layout. Here the user has developed a color scheme for classifying information objects concerning machine translation software, such as people, companies, publications, and software systems. The user's layout practices indicate specific relationships between the objects, such as relations between objects identifying a researcher in the field and their software projects and publications.

People make use of natural forms of communication when possible. In our study of systems that allow for visual expression, people often engaged in the opportunistic development of visual languages to match their activity. These languages have several advantages over the formal relationship models found in knowledge representation systems. They are easy to initiate: They start as simple categorizations. They evolve over time, not only in terms of the complexity of expression but also in terms of their meaning to their authors. The original classifications often change, becoming more semantically rigid as users' understanding of their task increases.

To enable the system to understand these emergent visual languages, we developed spatial parsers meant to recognize the object types and associations that people see when looking at

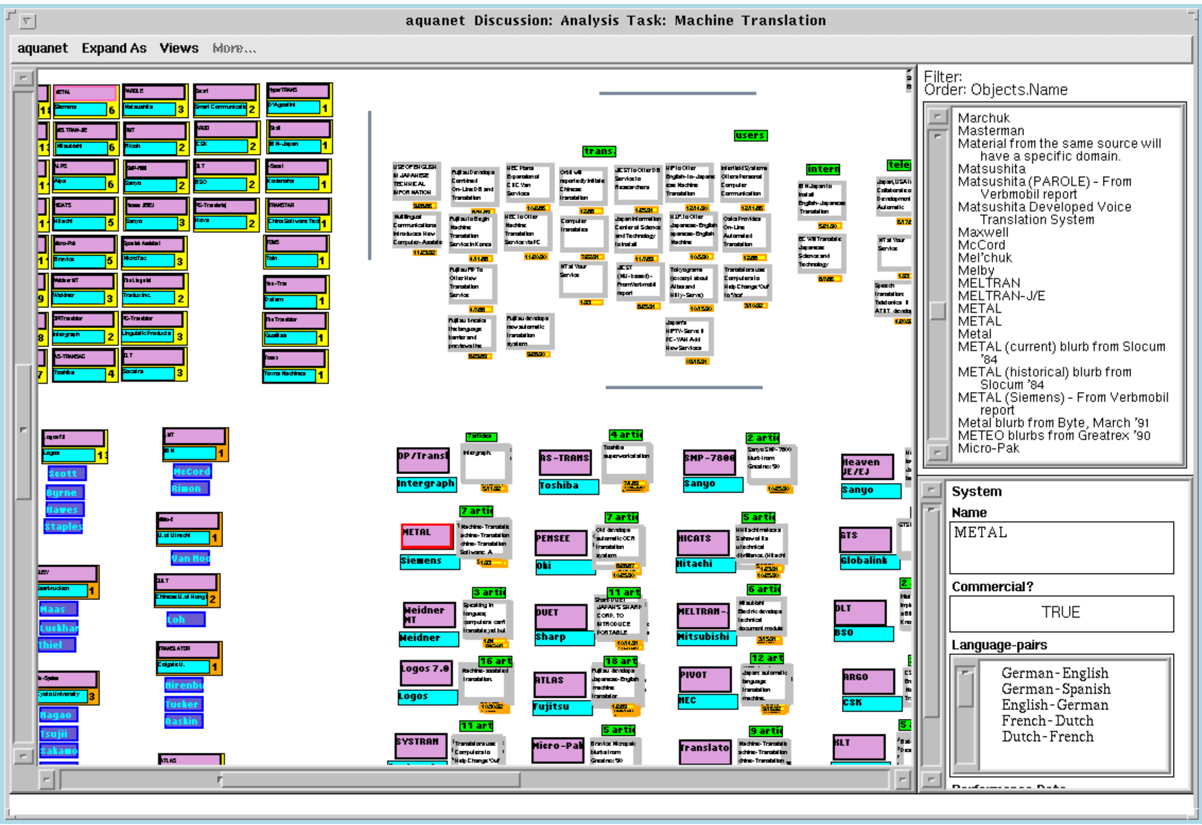


Figure 7. Visual structures expressing semantic relations between people, companies, publications, and software systems in Aquanet.

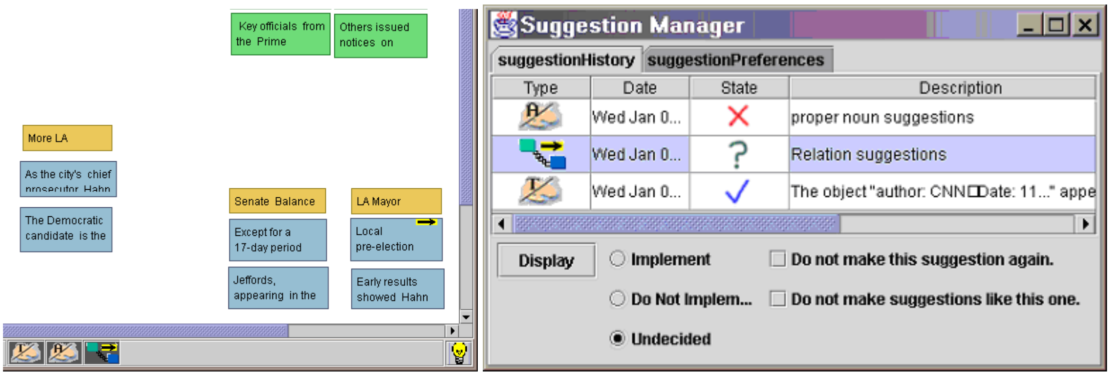
these layouts (Shipman et al., 1995). In VIKI (Marshall et al., 1994), the resulting relations were used to suggest formalizations, including the creation of templates for common association types and the creation of collections (i.e., subspaces) for regions containing coherent forms of expression.

The Visual Knowledge Builder (VKB) expanded on these suggestions by combining the results of spatial parsing with text analysis to generate term vectors for each of the structures recognized in the workspace. These term vectors were then used to make recommendations for where to place new information objects (Shipman et al., 2002). VKB also combined the spatial parsing results with temporal analysis to disambiguate interpretations of spatial structures. By keeping track of each edit to the workspace, it is possible to compare the structures recognized in prior states of the workspace to those recognized later. VKB used these differences to determine whether gaps in lists were likely to be semantically meaningful or a side effect of manipulations (e.g., removing an object from a list leaves a gap that would be meaningful if deliberate).

A lesson from earlier efforts to actively support incremental formalization is that users do not want to be interrupted from their main activity to address potential formalizations. Earlier versions of VKB included a Suggestion Manager that presented suggestions through progressive exposure. When a formalization suggestion was available, an icon would appear in the bottom area of the window and would gradually fade away (see Figure 8a). Several suggestions could be visible at once. The user could mouse over the suggestion icon to gain more information about the suggestion. By clicking on the suggestion the user brings up the Suggestion Manager in order to implement suggestions or to tell the system to quit making specific suggestions or classes of suggestions (see Figure 8b). Because users may not be ready to evaluate or make use of a suggestion when the system initially generates it, the Suggestion Manager retains a history of suggestions so users can explore them later, when they have the time.

While we learned a number of lessons about the generation and presentation of suggestions for formalizations, one problem remained. Most uses of VIKI and VKB do not require formal representations. While they could theoretically benefit from the generation of a formal representation, the cost–benefit trade-off was never favorable for that to occur.

Today, VKB and other spatial hypertext systems do not attempt to expose the formal structures to the user, instead using the results of spatial parsing, text analysis, and temporal



a) Icons at bottom indicate suggestions **b) Suggestion Manager shows past suggestions**

Figure 8. Suggestions in VKB aim to decrease effort required to capture semantics. The left figure shows icons indicating new suggestions while the right side shows suggestion details.

analysis to generate formal representations only used within the systems. The DE Analyzer mentioned earlier uses a spatial parser to recognize structures of widgets in interface window constructions (Moore, 2007). These are used to provide navigational opportunities to structures intermediate in scale between widgets and windows. A somewhat similar use of spatial parsers is to identify structures in order to apply transforms for adaptive spatial hypertext (Francisco-Revilla & Shipman, 2004). By understanding what objects are in what visual structure, geometric transforms can be applied that maintain the coherence of the layout. Spatial parsers also are used as evidence of people's opinions about similarity. MusicWiz includes a spatial workspace for organizing the elements of a music collection and visual expression is used as one of many components in calculating the similarity between two pieces of music (Meintanis & Shipman, 2010). Finally, application of spatial parsers to Web pages has been used to provide access to visual structures to the visually impaired (Francisco-Revilla & Crow, 2009).

One lesson from these experiences is that people will use natural means of communication to express information that could be more valuable if formalized. Another lesson is that formalization must be in support of a real problem. Many times information does not need to be formal, at least in terms of how users interact with the information. In design, formalization is a necessary part of specification and can be valuable in task decomposition, assignment, and tracking. For some uses of rationale, designers do not need to formalize the rationale by encoding it in a particular representational framework. Much like with the end use of the results of the spatial parsers, relations between design information can be inferred and tracked by the system in order to provide useful services without requiring designers to ever acknowledge or commit to these relations.

IMPLICATIONS

As the previous sections document, we have explored a variety of themes related to the synergy of collaborative design rationale and social creativity made feasible in cultures of participation. Numerous other challenges remain, including (a) learning environments to become a contributor (Preece & Shneiderman, 2009), (b) minimizing the effort required to learn how to contribute in order to avoid participants being taken off-task and not getting their work done (Carroll & Rosson, 1987), (c) the role of curators in organizing large living information repositories, (d) rating mechanisms for identifying the quality of information, and (e) tagging mechanisms to allow all stakeholders at all times to provide more design rationale.

One of the most important challenges for design rationale research has been the question, What motivates participants to contribute (Grudin, 1987)? To motivate participants to contribute design rationale, the following questions need to be answered: (a) from an individual perspective, Am I interested enough and am I willing to make the additional effort and time so my voice is heard? and (b) from a social perspective, How can we encourage individuals to contribute to the good and progress of all of us? These questions indicate the importance of motivation and rewards in persuading people to make their voices heard and create the following objectives:

- change making must be perceived as within the skill and experience level of users (creating the requirement of systems with a low threshold and high ceiling, and learning and performance support (Shneiderman, 2007);
- changes must be technically possible (by supporting interaction mechanisms suited for end-user development); and
- benefits must be perceived (creating the requirement that participants must perceive a direct benefit in contributing that is large enough to outweigh their effort).

Since human beings try to maximize utility, increasing the value and decreasing the effort of contributing design rationale is essential. Utility can be defined as the relationship between *value* and *effort*, or the difference between effort expended for value gained. A sufficiently high utility factor can be obtained through a combination of

- *increasing the value* for being an active contributor, including mechanisms and rewards, such as allowing people to be in control, mastering a tool in greater depth, making ego-satisfying contributions, and acquiring social capital;
- *decreasing the effort* in making a contribution by creating support for learning to become an active contributor, extending metadesign to design communities by allowing local developers and gardeners to emerge (Nardi, 1993), and automatically collecting design rationale by channeling as much as possible of communication between participants through the computational environment.

Figure 9 illustrates this objective as we have pursued it in the EDC. The left diagram shows that all communication between the participants takes place outside the computational environment (and therefore is not available as design rationale), whereas in the right diagram as much communication as possible is channeled through the environment, gets captured, and can be used as design rationale.

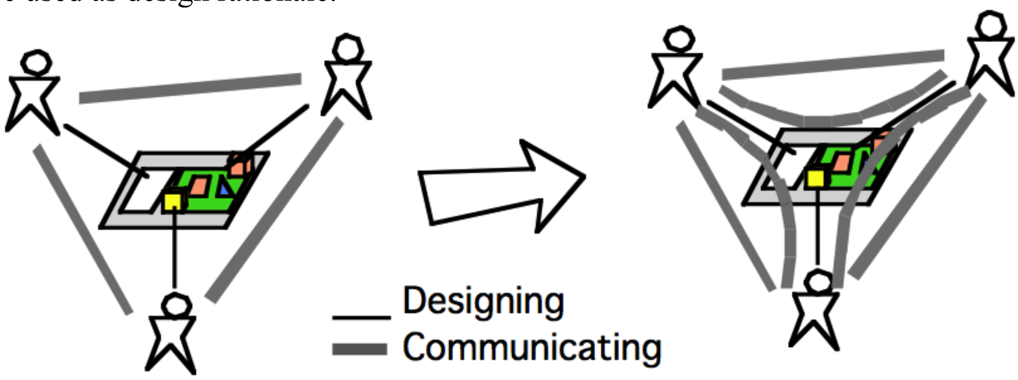


Figure 9. "Storing the Artifact" versus "Mediating Design and Communication" architectures.

CONCLUSIONS

This paper provides arguments, frameworks, and case studies advocating coordinating and integrating collective design rationale and social creativity to create new synergies and opportunities, particularly in the context of complex, open-ended, and ill-defined design problems. Grounded in our previous explorations of design processes, design rationale, and creativity, we have described an emerging framework and case studies to demonstrate that the assumption that design rationale and creativity are at odds with each other is misleading. Cultures of participation, supported by sociotechnical environments, have the potential to exploit the opportunities provided by the synergy of collective design rationale and social creativity.

ENDNOTE

1. See http://sketchup.google.com/3dwarehouse/ for examples.

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