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**SPECIAL ISSUE ON CREATIVITY AND RATIONALE
IN SOFTWARE DESIGN, Part 2**

John M. Carroll, Guest Editor

Pertti Saariluoma, Editor in Chief

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From the Editor in Chief**INTUITIONS IN HUMAN–TECHNOLOGY INTERACTION DESIGN**

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While science is interested in how things are, design concerns more how things should be in the world. While both focus on the common the pursuit of improving the quality of human life, they are different in many respects. One of the differences is the way intuition is applied.

Here, the word *intuition* has a specific meaning: It refers to subconscious foundations of thinking and thoughts. In science, grounds and arguments are key. Empirical observations are made in a controlled and methodical manner to give as much certainty as possible to the facts. Nevertheless, full certainty can never be reached (Nagel, 1961; Saariluoma, 1997). Moreover, it is easy take something as it is without even paying attention to it (Saariluoma, 1997; Wittgenstein 1969). These tacit and barely explicated foundations of scientific thinking are called intuitions.

Intuition is not only about empirical work, but also is involved in mathematical thinking. Euclid, for example, assumed that one line, at most, can be drawn through any point not on a given line parallel to the given line in a plane. However, by giving up this assumption, mathematicians are able to create nonEuclidian geometries. This means that Euclid's idea, apparently very true under given assumptions, was just an intuition. In other situations, another intuition could be used. Similarly, hundreds of years later, behaviorists used to think that mental concepts were not relevant in psychology (Watson, 1919), but this proved to be too strong an assumption during the rise of cognitive psychology.

Logically, scientific truths make assumptions concerning reality, and therefore they rely on intuitions. We can look for grounds but, because we cannot have endless chains of arguments, at some stage we have to establish our knowledge on intuitions. This rather abstract truth has practical consequences. For example, human attention used to be described in terms of capacity, but this no longer is believed to be the only way (Broadbent, 1958; Covan, 2000). Clinical attention research leads scholars to suggest that certain mental contents may affect attentional information processing so that, for instance, agoraphobics process threatening words differently than neutral words (McNally & Foa, 1987). It was just an intuitive assumption that capacity is the only important perspective to attention.

Intuitions are problematic in science. It is not that they necessarily would be incorrect; no doubt some intuitions are correct. The problem is that, in the absence of argumentative backing, one cannot be sure whether or not they are true (Saariluoma, 1997). It may be that they are valid in some contexts but invalid in others. The scientific community just cannot know

what these tacit assumptions mean to the validity of scientific ideas. Returning to the example of the behaviorists, they did not make false observations but, from a contemporary point of view, their thinking was limited.

What is interesting, then, considering the scientific challenge of intuitions, is that they nevertheless advance science. The cognitive revolution replaced behaviorist intuitions with different intuitions, and immediately psychology progressed into new areas. Galileo and Kepler found anthropocentric and geocentric intuitions unfounded, and Einstein reworked the assumptions about the nature of universe. In all these cases, science significantly advanced. This means that explicating and reforming unfounded intuitions is an essential mechanism for the advancement of science.

Intuition in the field of design, however, plays a very different role: Design thinking is intuitive in concerns about the future states of affairs. Good intuitions are the very soul of good design. The creation of Facebook needed no scientific theories; the creators simply had a great vision. The innovators of the wildly popular *Angry Birds* game claim they have no idea why it has become a worldwide sensation. Indeed, intuitions are very relevant in attempts to understand design thinking.

In design, good reasons are not always apparent for every solution. Sometimes designers just have to trust their intuitions, even if they do not know whether these intuitions are true or false. However, as long as the success stories remain at the forefront of minds and literature, it is easy to miss the downside of design intuitions. In reality, intuitions may very much be incorrect, and much work can be invested needlessly in chasing phantoms.

In other words, by focusing on the success of *Angry Birds*, it is easy to overlook the scores of other games created that same year that never gained an audience. Perhaps they were based on incorrect intuitions. The story of WAP has been repeated many times, but serves as a good example (Saariluoma, 2011). It illustrates how companies may base their design processes on ideas that will not work. In the case of WAP, the developers incorrectly assumed that people could and would learn about and enjoy using it. Incorrect intuitions are actually very common in design.

When applying intuitions, several outcomes are possible. The design intuitions may be correct and successful, as in the case of the Ford Mustang. Or, it could be assumed that people like a product based on intuition, but they do not, as in the case of the Ford Edsel, resulting in loss of time and money. Or, it may be that the design idea is correct, but the designers' intuition on the idea is mistaken; a good idea is abandoned until someone else comes along and turns it into a success, as in the case of the touch screen. Thus intuitions take place not only in design thinking, but also, and especially critically, in management decision making.

So how do designers, and individuals and communities, address the challenges of intuition in design thinking? The only solution is to explicate the assumptions. This means that intuitions must be critically scrutinized. Before an idea gets too old, the designers need to formulate the underlying assumptions and become socially aware of them. This process can then decrease the number of design errors caused by false intuitive assumptions.

For example, usability testing on the WAP technology showed as early as 2000 that it was not likely to work as envisioned (Ramsay & Nielsen, 2000). Nevertheless, the work continued under the intuitive assumptions that the technology would become a household concept. On the other hand, a paper machine corporation assessed an extended nip concept as too complex and rejected it. However, as a consequence of a factory purchase, they had to

return to the idea and reinvestigate that technical solution. Consequently, they became a world technology leader in paper machines (Saariluoma, Nevala, & Karvinen, 2006).

Usability studies are not the only method of explicating intuitions. Another important method is requirements engineering, because requirements are explicated intuitions. They give form to the goal of product design and design rationales in human–technology interaction. Explicit requirements allow for discussing whether or not intuitions make sense.

In summary, intuition plays a role both in scientific and design thinking. Moreover, intuitions particularly are relevant when considering the generation of new ideas and the advancement of technologies. It is fortuitous, then, that *Human Technology* has been able to publish this second set of papers in the two-part special issue on creativity and rationale that investigates the relations of design rationale and the advancement of design thinking.

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Guest Editors' Introduction**CREATIVITY AND RATIONALE IN SOFTWARE DESIGN**

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Creativity and rationale are two lenses for looking at design. Obviously, design is about envisioning new artifacts and experiences through the embodiment of new ideas. But design also is clearly about understanding reasons and balancing trade-offs in order to develop new artifacts and experiences that are desirable and effective, and not merely novel. Because disciplines and predilections tend to fragment and specialize human activity, it can appear that creativity and rationale are about fundamentally different endeavors, although both happen to be known as *design*. This is profoundly unfortunate; to the extent that such a dichotomy prevails, it more or less ensures that no adequate treatment of design can emerge.

The possible disconnection between creativity and rationale in conceptualizing design evokes the image of Janus: two faces looking in opposite directions, unlikely to ever see the same thing, or to see enough in common to make integrative sense of anything. A more inspiring image might be that of the Taijitu symbol for yin and yang, smoothly integrated opposites flowing into one another, and depending upon one another for their meaning.

The Workshop

During June 15-17, 2008, a diverse group of designers and design researchers met at Penn State University to exchange perspectives and approaches, to articulate and develop new research ideas and hypotheses, and to reconsider and reconstruct prior work and results toward new research directions.

The workshop included thought leaders from several software design research communities: human-computer interaction design, sociotechnical systems design, requirements engineering, information systems, and artificial intelligence. The attendees were Mark Ackerman, University of Michigan; Eli Blevis, Indiana University; Janet Burge, Miami University of Ohio; John Carroll, The Pennsylvania State University; Fred Collopy, Case Western Reserve University; John Daughtry, The Pennsylvania State University; Umer Farooq, The Pennsylvania State University; Gerhard Fischer, University of Colorado; Jodi Forlizzi, Carnegie-Mellon University; Batya Friedman, University of Washington; John Gero, George

Mason University; Steve Harrison, Virginia Tech; Sal March, Vanderbilt University; Raymond McCall, University of Colorado; Rosalie Ocker, The Pennsylvania State University; Colin Potts, Georgia Institute of Technology; Mary Beth Rosson, The Pennsylvania State University; Al Selvin, the Open University and Verizon; Alistair Sutcliffe, University of Manchester; and Deborah Tatar, Virginia Tech.

The workshop premise was that creativity and rationale should not be disjoint worldviews, and that coordinating and integrating them is key to having more effectively reflective design practices, which in turn is absolutely essential to a serious science of design. Like most workshops, this one ended up posing, but leaving open, many questions, as well as identifying projects that ought to be undertaken, but have not yet been started.

This Special Issue

A key objective of the workshop was to facilitate longer term processes of scholarly interaction toward the development of more refined proposals, analyses, and results. One means of advancing this objective involves scholarly publishing. This issue is the second of a two-part special issue on Creativity and Rationale in Software Design; the first installment appeared as Volume 6, Number 1, of *Human Technology: An Interdisciplinary Journal on Humans in ICT Environments* in May 2010. For more extensive introductory framing, please see Carroll (2010).

The four papers in this issue examine the relationships and synergies between creativity and rationale in software design at different levels of analysis. The first paper “Achieving Both Creativity and Rationale: Reuse in Design with Images and Claims,” by McCrickard, Wahid, Branham and Harrison, addresses the technical issue of reuse: Designs are almost never ab initio; they typically are based upon prior designs. McCrickard et al. operationalize rationale as the explicit articulation of values and trade-offs implicit in a design, and investigate how to encourage the reuse of rationale toward better designs and greater creativity.

Farooq and Carroll, in “Supporting Awareness in Creative Group Work by Exposing Design Rationale,” address the level of small design teams and the challenge of maintaining team activity awareness in producing a creative collective outcome. For example, team members must monitor the development of key ideas across the team in order to be able to coordinate their own contributions, and to communicate with their teammates. Farooq and Carroll investigate the consequences of sharing rationales around work activities through status updates in a collaborative environment to support overall team awareness.

In the third paper, “Mining Creativity Research to Inform Design Rationale in Open Source Communities,” Burleson and Tripathi investigate the role of rationale in open source communities. This is an interesting paradigm of software and do-it-yourself development with respect to creativity, since membership in open source communities is voluntary. Burleson and Tripathi describe practices of these organizations that cultivate informal rationale, specifically enabling them to codify knowledge from recent project activities and to apply that knowledge in future projects.

Fischer and Shipman, in the final paper, “Collaborative Design Rationale and Social Creativity in Cultures of Participation,” address the succession of cultural paradigms, from a *consumer culture*, in which people are users and relatively passive with respect to designs, toward *cultures of participation*, in which users are designers and redesigners. In this view, it

is possible, indeed necessary, for design rationale to be articulated by and accessible to anyone and everyone. Moreover, it is permitted, indeed expected, that everyone's creative contributions can be heard and considered in addressing the widest variety of contemporary design problems. Fischer and Shipman argue that the emergence of cultures of participation provides new ways to reconcile creativity and design rationale.

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ACHIEVING BOTH CREATIVITY AND RATIONALE: REUSE IN DESIGN WITH IMAGES AND CLAIMS

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Abstract: Although designers often try to create novel designs, many designs are based on previous work. In this paper we argue for the reuse of rationale, in the form of claims, as a central activity in design, and explore how this can be used to inspire creativity. We present a design activity in which images and claims are reused to create a storyboard and illustrate how creativity and rationale complement each other. Our work serves to demonstrate that an appropriate design activity can be used to leverage creativity with the use of rationale.

Keywords: reuse, creativity, rationale, claims, images.

INTRODUCTION

The formal and mechanized nature of many design rationale methods may seem a hindrance to the creative process, inhibiting the natural flow of ideas that is so important to groundbreaking concepts. However, by ignoring the lessons learned by others, a designer may risk lacking the knowledge to put forward potentially creative ideas. In this paper we explore ways to present design rationale that help stimulate the creative process, while providing at the appropriate time a bridge to design rationale. In particular, we consider how the representation of images—a familiar construct in many creative activities—encourages designers to generate novel ideas as a first instinct, with the rationale enabling the desire to justify, compare, and build toward a solution.

One important approach to leveraging design rationale is appropriate knowledge reuse, wherein previously created artifacts are considered in the design process toward creating a design that might be an improvement over a prior solution. Many practitioners exercise

knowledge reuse informally by basing new solutions on old experiences: Products developed previously could be used in new ways, distinct ideas can be connected together, or evolutions of previous products can be made possible through technological advances. When new products are created, designers tend to naturally reuse techniques of the past—providing impetus behind an often-ignored need to gain and even build on what has been used before (Whittaker, Terveen, & Nardi, 2000).

New designs built with formal design rationale approaches show promise in enabling designers to think deeply about the trade-offs presented in each design decision towards lowering costs (Bias & Mayhew, 2005) and improving usability (Wania, 2008). Prior efforts within interface development communities have investigated ways of facilitating the reuse of various components, often rooted in design knowledge capture (Borchers, 2000; Hughes, 2007; Landay & Borriello, 2003; Sutcliffe & Carroll, 2000). However, constraints placed in design rationale systems, such as formalized structures and processes, can hamper the effectiveness of creative workers (Horner & Atwood, 2006).

Creative ideation is often seen as beneficial since it can spark new directions with the potential to lead to interesting and novel designs. Quality creative ideas balance novelty with appropriateness (Amabile et al., 1996; Bias & Mayhew, 2005), often with a role for appropriate information acquisition and selection. Even though there are many avenues to creative design, it is essential to consider how well the generated ideas fit with the intended design.

In this paper, we put forth the position that those engaged in design may benefit from both creative ideation and rationale-based reasoning centered around reusable features. Although new ideas might lead to fresh ways of thinking about technology, we believe that their value may be increased when grounded in reasoning acquired through previous efforts. Creativity and rationale are not, a priori, opposing forces, but rather could be made complementary when encapsulated in appropriate design artifacts. We reason that lightweight rationale buffered by rich pictures and an engaging storyboarding activity may be one solution to this challenge.

Therefore, we explore the role of creativity and rationale in reuse with emphasis on the *claim*—a form of rationale capturing a feature and its design trade-offs (Carroll & Kellogg, 1989). We articulate the advantages of leveraging rationale, but also acknowledge the need to ease its reuse in design. Thus, we investigate the nature of creativity, leading to the role that *imagery* can carry out in aiding claims reuse. In an effort to further explore this space, we created domain-specific cards that merge imagery and claims together. We also present one technique, a design activity in which these cards are used to construct storyboards, and reflect on the role of creativity and rationale during reuse.

RATIONALE AND REUSE

When practitioners approach design problems in search for answers, they rely on internalized reasoning as well as the reuse of past experiences and solutions. Formal rationale reuse methods try to mimic and improve upon these aspects of design with more explicit, externalized representations of knowledge. As digital or physical artifacts, reusable design rationale units provide focus points for dialectic collaboration and offer generalized solutions for contextualized consideration. Moreover, they open opportunities for design knowledge to traverse the gap of time and space between teacher and pupil, or between peers with different perspectives.

History includes many methods for capturing and associating knowledge, toward making it more accessible to researchers. As stores of knowledge grew in the early part of the 20th century, visionaries like Paul Otlet (Wright, 2007) and Vannevar Bush (1945) presented grand schemes for capturing, linking, and accessing knowledge. Their focus was not merely on classifying collections of books, but on identifying the core knowledge units within them that appropriately capture the essence of the contribution.

Design rationale emerged from the inherent bounded rationality of design thinking and wicked nature of design problems (Rittel & Webber, 1973; Simon, 1996). These notions were encapsulated in the issue-based information system (IBIS) model of design argumentation, which structures discourse by design topic, issues, arguments, and questions of fact that are raised in design dialogue (Kuntz & Rittel, 1970). MacLean, Young, Bellotti, and Moran's (1991) questions, options, and criteria (QOC) presents a more formal design rationale model, encompassing questions about the design space, alternative design options, and criteria for selecting the solution. In a less formal representation, case studies capture the key rationale that results in observed design outcomes (Borchers, 2000; Harvard Business School, n.d.).

Perhaps the component most commonly associated with reuse in interface design is the pattern (Borchers, 2000; Landay & Borriello, 2003; Lin & Landay, 2008; van Duyne, Landay, & Hong, 2007; Yahoo! Developer Network, n.d.). Originally proposed by Alexander, Isikawa, and Silverstein (1979) for the design of buildings and towns, patterns are reusable design knowledge components. They include information such as context of use, conflicting forces, and potential solutions—components that incorporate design rationale. Prepatterns are forms of patterns used in emerging design domains (Saponas, Prabaker, Abowd, & Landay, 2006).

Similar to the pattern or case study, but of a different scale, is the claim. First introduced by Carroll and Kellogg (1989), claims document the psychological effects of user interface features in context. Although claims were initially proposed as disposable knowledge units (e.g., Carroll & Kellogg, 1989; Rosson & Carroll, 2002), they have since been identified to be of appropriate granularity for reuse (Payne, Allgood, Chewar, Holbrook, & McCrickard, 2003; Sutcliffe & Carroll, 2000). Through these transitions, the claim has taken on differing shapes and sizes. In this paper, we focus on its simplest form: a feature coupled with usability trade-offs (Figure 1).

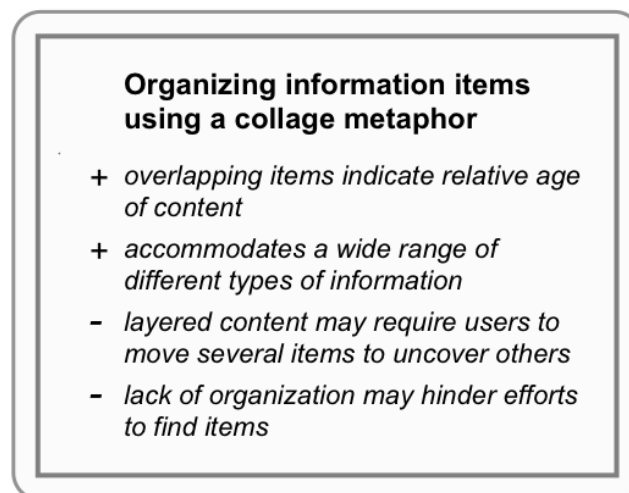


Figure 1. An example claim with a feature, upsides, and downsides.

Some claims, as illustrated by our example in Figure 1, are based upon scientific findings (Greenberg & Rounding, 2001). Others may be generated by designers based upon experience or intuition. The contextualized nature of a claim's creation may alter the relevance and meaning of upsides and downsides when claims are reused in new design situations. Although these characteristics may result in varying claim quality, there is an important contribution beyond explicit transfer of design knowledge. Claims motivate design reasoning, particularly because they call attention to trade-offs and encourage designers to increase positive impacts (Rosson & Carroll, 2002). In addition, claims documented by one designer in a unique design situation may provide an outsider's perspective to future designers that interact with that claim. Claims, then, are not just about an explicit hand-off of expert knowledge; they are instead about designer engagement with external perspectives in a user-centered, trade-offs-oriented mindset.

Claims, like patterns, are discrete units of design knowledge. One salient departure is the structure and depth of information captured in each rationale unit. Where a single pattern may fill a dozen pages (van Duyne et al., 2007) and consist of many different parts, such as a synopsis, background, problem, solution, forces, and evidence (Saponas et al., 2006), a claim in its basic form encapsulates a feature description with its design trade-offs (Rosson & Carroll, 2002). Although we acknowledge patterns can emerge in different sizes, we submit claims as a viable alternative to patterns since their difference in structure may make claims designer digestible—quick to read, comprehend, and act upon (Carroll & Kellogg, 1989).

Claims may be informally and quickly drawn up in the heat of design situations with minimal interruption to design activities. Of course, the test of whether or not designers actually capitalize on this opportunity relies upon sufficient designer buy-in to design rationale reuse; we believe it can be achieved with the framing of an appropriate design activity. Hence, we find claims one suitable form of rationale because they have the potential to both provide insight at design prototyping time as well as capture lessons learned in situ that may be passed on to designers in different times, places, and contexts.

Although design rationale played a larger role earlier, it is now true that design rationale is not widely used (Carroll, 2003), in part because it is prone to capture, retrieval, and usage limitations during design (Horner & Atwood, 2006). Keeping this in mind, we acknowledge that claims are also subject to potential negative consequences. When faced with a large collection of claims, it can be burdensome and time-consuming for designers to investigate claims because of their textual nature—necessitating quick recognition of the essence of claims. It is also quite possible that a designer might have a different view of the feature, but this may potentially influence or eliminate a designer's independent consideration of what the impact of the artifact might be and how it may be used. Designers need to think for themselves to further develop their own understanding of an artifact instead of immediately being exposed to the bias of the claim itself. Only then can a claim serve to challenge designers' own understanding of the artifact. Creating a claim can encourage designers to think for themselves and draw on their own experiences. However, a source of inspiration for new features that might go hand in hand with the existing claims would benefit designers greatly. A new way to represent claims that can inspire designers through creative means is needed to reduce the negative impact during reuse.

CREATIVITY SUPPORTING REUSE

Creativity has long been a trait sought in design process—it is the source of new ideas, new products, and new hope for human discovery. And yet, researchers are still working to describe and explain the creativity phenomenon. Creative acts can even take on many different forms (Harrison & Tatar, 2008). The result is a varied set of equivocal conceptions of creativity and an abundance of questions yet unanswered. Definitions of creativity range from the creative process (e.g., Amabile, 1983; Hogarth, 1980; Osborn, 1963; Shneiderman, 2000; Sonnenburg, 2004; Wallas, 1926), to the creative person (e.g., Guilford, 1950; Lubart, 2005), to the creative product (e.g., Amabile, 1982; Boden, 1994). As human–computer interaction (HCI) researchers, our concern with creativity is twofold: Not only are we deeply engaged with questions of how technology can enhance creative endeavors, but—and this second obligation often goes neglected—we also are invested in supporting creativity in our usability design processes. The latter of these is a key focus of this work.

There is a common misunderstanding about the definition of creative products: It is often assumed that creative products must only satisfy the singular criterion of novelty. Certainly, a creative idea must be new, at least to the immediate creators (Bias & Mayhew, 2005), but that is not sufficient. Creative ideas must also exhibit appropriateness (Amabile et al., 1996). That is, the idea must solve a problem, be useful and usable, and otherwise satisfy measures of quality.

Generating creative ideas can be considered as the reuse of existing knowledge to elicit new knowledge: “Although cases of insight do occur, more often than not creative thought calls for information acquisition and the selection of appropriate concepts for understanding this information” (Mumford, 2000, p. 315). Furthermore, creativity is often the result of the fusion of existing knowledge from disparate domains: “Creative novelty springs largely from the rearrangement of existing knowledge—a rearrangement that is itself an addition to knowledge. Such rearrangement reveals an unsuspected kinship between ‘facts long known but wrongly believed to be strangers to one another’” (Kneller, 1965, p. 4). Recombinations of existing knowledge can sometimes be viewed as crossing boundaries between fields to apply an analogous solution to a new problem (Thomas, Lee, & Danis, 2002). These types of recombinations can sometimes be achieved through lateral thinking techniques, whereby diverse stimuli are used to initiate novel connections (De Bono, 1990).

Another important aspect of creativity is its temporal span; it is a staged process that can vary from moments to days in duration. One of the foundational models, conceived by Wallas (1926), includes the transition of an individual through four sequential phases: preparation, incubation, illumination, and verification. Preparation is marked by the gathering of existing information and domain knowledge in response to a motivating problem; it is a period during which the creator “reads, notes, discusses, questions, collects, explores” (Kneller, 1965, p. 48). During incubation, the knowledge gained through preparation is left to steep and the problem, perhaps, is even forgotten altogether. In a moment of unconsciously driven illumination, the creator happens upon a novel solution. In the final phase, verification, the implications of the speculative solution are consciously considered and revised for appropriateness. More recent constructions of the creative process (e.g., Amabile, 1983; Hogarth, 1980; Osborn, 1963; Shneiderman, 2000; Sonnenburg, 2004; Wallas, 1926) still include these foundational phases at an abstracted level.

In this staged process, idea illumination and idea verification are separate phases and may take place one before the other (as formalized in Osborn's, 1963, brainstorming process). With respect to user-centered HCI design, we consider this an opportunity to balance images (i.e., rich stimuli that may aid idea generation) and reusable design rationale (i.e., a cognitive tool that may aid idea assessment) in a combined artifact-based activity. We propose that, by presenting images first, the initial focus will be placed on the creation of novel ideas without immediate attention to whether ideas fit both the novel and appropriate constraints. And, presenting rationale second may allow novel ideas to be explored before being reined in by rationale in the assessment of appropriateness. The next two sections explore reusable rationale and images, respectively, as complementary components for enabling the creative process.

Pictures, images, and sketches have been incorporated in a number of creative design activities for their ability to stimulate divergent thinking. In creative writing, pictures “sparks” are used to help inspire a new story direction (Kellaheer, 1999). Trend cards, each comprising a short textual fact about a target market and related picture, are used in industry to stimulate brainstorming sessions (Smith, 2009). The Creative Whack Pack (von Oech, 2008) and the Thinkpak (Michalko, 2006) use sketches and images to encourage creative problem finding and problem reframing. Picture-based artifacts that promote creativity are also beginning to appear in HCI design methods in the form of product example pictures (Herring, Chang, Krantzler, & Bailey, 2009) and cards that capture values (Nathan, Friedman, & Hendry, 2009). Most existing image-centric creative design activities are strong on brainstorming and idea generation, but do not focus on issues of appropriateness and rationale.

In this paper, we consider images of system features or of symbols thereof not only because this fits the granularity of our chosen unit of design rationale, but also because features may be an appropriate unit for sparking creative ideation. We believe that pictures of system features—objects and symbols captured as moments in rich context—are evocative stimuli that may provide a platform for lateral thinking. This type of thinking spawns novel connections between stimuli—pictures of features—and the problem domain. Furthermore, a pool of diverse feature pictures spread out on a surface such that most are visible at the same time has potential to provide opportunities for novel recombination and rearrangement of existing ideas. Finally, because the visual nature of pictures allows them to be seen and understood in little more than an instant, it may allow designers to flow fluidly between ideas as they “read” each image, thus supporting the preparation and incubation stages of creative ideation.

IMAGE AND CLAIM REUSE IN STORYBOARDING

Storyboards are visual narratives that include actors engaging in a series of actions toward a common goal. Typically, they consist of multiple panels made of pictures and an accompanying narrative that illustrates a temporal progression. Key aspects of a storyboard are the portrayal of time, the inclusion of people and emotions, the inclusion of text, and the level of detail (Truong, Hayes, & Abowd, 2006). Used by those involved in the creation of movies, cartoons, and commercials, they are powerful tools for thinking through and presenting the most important aspects of a narrative (Finch, 1973; Hart, 1999).

In HCI, storyboards have been used in the design process to illustrate how users may interact with a system (Buxton, 2007; Sharp, Rogers, & Preece, 2007). Primarily used in early prototyping phases, storyboards in this domain describe the user's interaction with a system over time through a series of graphical depictions, often sketches, and units of textual narrative. Storyboards have been used to help understand the flow of the interaction scenario, to eliminate costly elements of a design, and even to decide how to pitch ideas to others (Buxton, 2007; Rosson & Carroll, 2002).

Reuse has been supported in the storyboarding process, both formally and informally. The earliest storyboards of films and cartoons used reusable components of characters (Finch, 1973). Storyboarding tools such as SILK (Landay & Myers, 1995), DENIM (Newman, Lin, Hong, & Landay, 2003), and DEMAIS (Bailey & Konstan, 2003) facilitate storyboarding to create prototypes early in design and support reuse through cutting, copying, and pasting of images within and between storyboards. As in our process, the Damask storyboarding tool leverages the reuse of patterns, although the authors acknowledge that the size of many patterns made them difficult to understand (Lin & Landay, 2008).

In our process, we seek to leverage and combine prior work in design rationale, creative inspiration through images, and storyboarding through an image-centric artifact set. Each artifact is presented in the form of a card depicting a feature through an image and label on the front and an associated claim on the back (see Figure 2). We chose to place representative images and brief titles on the front of each card with the expectation that artifacts would be quickly recognized and designers would gain inspiration from the artifacts. In so doing, we expect that they would first consider broad possibilities of how the artifact could be used in design before being influenced by the claim on the back. However, the claim could serve as a gateway to formal design rationale, encouraging designers to consider the validity of their ideas in light of the rationale.

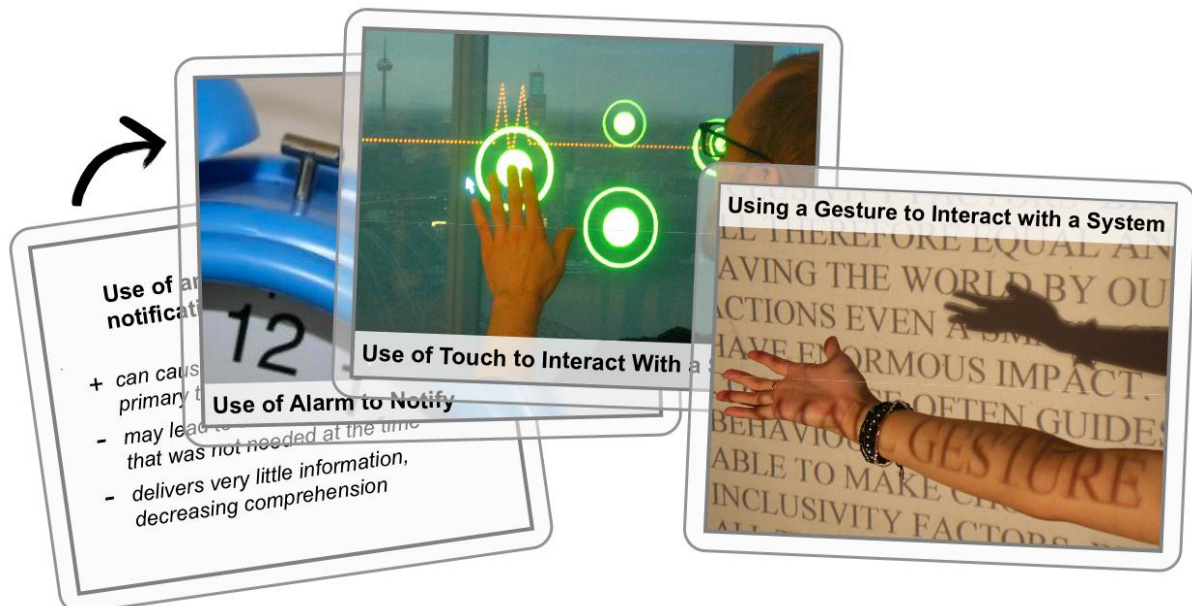


Figure 2. Card fronts have pictures with labels to represent features, and card backs present textual claims with user-centered trade-offs.

To explore this area, we are developing a method to facilitate the creation of storyboards by reusing premade artifacts for the creation of notification systems, tools that allow users to monitor information in dual-task situations (McCrickard, Chewar, Somervell, & Ndiwalana, 2003). Our initial work led us to investigate the use of these cards in design sessions, where we asked groups of three to utilize the artifacts in creating a prototype of a notification system (Wahid, Branham, Cairco, McCrickard, & Harrison, 2009). Twenty-one graduate students were gathered to take part in seven sessions for the study. In each design session, the participants were presented with one unique problem and asked to create an appropriate notification system. Some of the design problems we assigned involved notifying nuclear plant operators of changing core temperatures, passengers in airports of flight status changes, commuters of empty parking lot spots while driving, theme park visitors of ride wait times, and students of empty spots for classes they wish to register for.

All participants were actively engaged in conducting HCI research or enrolled in a graduate HCI course at the time of the study. Their familiarity with storyboarding and claims varied. Because we target our artifacts to novice designers as well, we preferred to recruit novice designers at this stage of our investigation. Here, we report on our observations of the balance of creativity and rationale centered about the cards.

Novice designers engaged in this design activity work to familiarize themselves with the set of cards, decide on what cards might be useful for the system they wish to prototype, and construct a storyboard by placing cards together. When needed, they created their own cards to incorporate new ideas. Our observations of this activity have allowed us to understand better how these cards are able to encourage designers to balance novel ideation and grounded reasoning. We provide below some examples from design sessions we ran showing how these cards impacted the construction of storyboards and provided opportunity for creative ideas along the way.

The use of imagery proves to be an important segment of the activity since it is a springboard for new ideas. One way in which imagery does this is by making ideas ready at hand. It enables quick digestion and recognition of reusable ideas, so much so that designers often find themselves considering all of the cards as potential candidates for their design—something often not the case when features must be read in the form of plain text. By making more features available to designers for ready consideration, we vastly expand the design space considered for assimilation in a design session. The pictures support, to a degree, universally understood communication of its direct message, the feature, and provide designers the space to incorporate the appropriate cards into their storyboard.

On the other hand, pictures also support different messages and interpretations of their contents. This proves to be another advantage of using imagery: inspiring the designers to think of other artifacts that might not have been considered, potentially leading to novel ideas. In many of our design sessions, we observed participants thinking of new ideas while viewing the images that were unrelated to the nature of the artifact the image presented. For example, we observed a group that reinterpreted a card about relating preexisting user knowledge to a notification generated by a system. The image used for this card was a picture of a chat window showing the chat history. A participant in the group looking at the card chose to focus on the message timestamp that was contained within the chat window and proposed that the timestamp be a feature incorporated into their storyboard. The timestamp happened to be a part of the image, but was not necessarily there to illustrate the idea of the

card. This serves to demonstrate that images can potentially inspire ideas that are beyond that of the claims themselves, leading to creative, divergent thinking patterns as well as a new source of knowledge to capture and store.

Images also afforded a platform for idea combination and domain transcendence—both tenets of creativity. Being that the pictures—which were taken in diverse times and places—all came together on a single table top, unique comparisons and couplings became possible and even natural. Participants placed pictures side by side for comparison and on top of one another for combination. As an example of feature combination, one group discussed joining a large-screen public display with a peripheral display to create a less distracting and user-driven source of information. Although the features we presented to participants were of the same domain (notification systems), we believe that there is promise in presenting an even more diverse set of images to designers to enable novel combinations.

The textual claims on the back of the cards serve as important ways for designers to consider the utility of the reusable ideas and to gauge how appropriate they are. Whenever designers need more information or have doubts about how to use an artifact, claims serve as a way of describing the artifact and its utility. The claim trade-offs play a vital role in allowing designers to decide whether the artifact should be used in a design. Designers turn to the textual claim when debating the impact of a feature—especially high-impact negative ones that they may not have realized. In one instance, we observed a designer become aware of a claim's downside articulating that a notification generated by the system might be missed by the user. The designer immediately found another card that might mitigate the effects of this downside. Claim trade-offs also aid in deciding between cards when alternatives present themselves. The advantage in having the textual claim is that it can provide designers with rationale-based design concerns that they have possibly not thought of to challenge or counter their own interpretation of the card—providing an alternative perspective to the consideration of the card. Ultimately, the presence of textual claim information makes the designers more aware of the need to consider carefully the reasons for including a feature in a design.

Creating new cards to capture new ideas in the form of pictures and claims is also an important part of the activity. In the sessions we ran, three new cards were created. Although we found that cards are often created as a result of an idea that was inspired by another card, it would be hard to identify whether it is solely because of the image or whether the associated claim played a role as well. For instance, a group decided to create a new card based on a card about graphical information because they wanted to create a system that also incorporated geospatial location, and therefore created a new card about geospatial representation of information. The group drew a picture of a map with various points of interest within it and created a claim that was largely a more specified version of the claim used for graphical information. Their need to refer to the other card demonstrated that they wanted to maintain the same level of scope, making it generic and trying not to overspecify the card so that its potential reuse would not be restricted. Thus, the authoring of the claim was influenced by the claims that were already around them. Although we see that new ideas can arise, we notice that these ideas are often grounded in other artifacts that inspired the designers. Even though creative thought inspired by the graphical information imagery provided a springboard for knowledge capture, the rationale ensured the designers considered the consequence of the new feature. The burdens of creating a new card in terms of content might have been lowered by introducing a

simple card structure, but we noticed that other factors, such as the designers' own knowledge and confidence in themselves, influenced whether a card was created.

Ultimately, the storyboard is constructed by choosing relevant cards, sequencing them according to a determined task flow, and then writing an accompanying narrative or scenario for each segment of the storyboard to solve the given design problem (see Figure 3). We acknowledge the final product of this activity is not a traditional storyboard since it does not enforce sketching. However, elements such as actors and the portrayal of time are still embodied within the narrative.

The construction process is also a careful interplay between creativity and rationale. Designers engage in exploring new ways to combine and order cards to create new functionality. For example, a new notification method could be created by combining a card about a blinking light with an audio notification card—leading them to either place the cards side by side or on top of each other. At the same time, their combined use is analyzed through the claims and further discussion on its potential effects. It is important to note that designers go beyond the individual cards and also focus on the system as a whole—testing out creative new task flows that result from a new sequence of artifacts. Although the participants chose the cards they felt were relevant to their goals, further investigation would be needed to understand which cards are prioritized depending on the given design problems and the eventual quality of the storyboards.

We believe that the nature of combined imagery and rationale is a primary factor in facilitating designers in brainstorming and considering consequences at the same time. Reusing ideas of the past may be beneficial, but the application of these ideas in new ways and forms may bring out potentially innovative solutions.



Figure 3. An example of a storyboard created by reusing the cards. The narrative serves to bring context and integrate the cards together.

CONCLUSIONS

Supporting reuse is an important step in bringing together creativity and rationale. To support the types of creative sparks we observed, a corpus of rationale is needed so that there can be a

ready source of inspiration and a variety of creative ways of combining them. We acknowledge that identifying new rationale can be beneficial, but believe that a preexisting, reusable set, especially at the start of a project, can serve these goals more effectively.

Even if reuse were to be supported, one could perceive that reuse, as a central tenet to design, can lead to uncreative and uninspired outcomes. However, this perception may be changed with the incorporation of mechanisms that inspire creative thought. In working toward this goal, careful thought must be put into the design of the reusable artifact and how those artifacts might interact with each other because that is where the creativity will most likely percolate. Although further investigation of our technique is needed, the combination of rationale and creativity for reuse seems to be a step toward provoking designers into creating innovative solutions and create a fresh source of knowledge that can be stored for others to reuse later.

Putting such a vision into practice requires that we identify appropriate mechanisms to capture rationale, inspire creativity, and construct meaningful prototypes. Claims are uniquely structured to capture knowledge in a designer-digestible manner to support reuse, and appropriate images associated with the claims summarize the message while facilitating ideation and reinterpretation. Because of their structure, they can be authored easily with limited effort—reducing the burdens associated with formal capture of rationale.

These knowledge-capture and presentation mechanisms (claims and images) must come together through a meaningful design activity. In our case the activity happens to be storyboarding, but other prototyping activities might prove to be equally useful. Because storyboarding is a creative and fun way to illustrate both visually and textually the task flow of a new system, it leverages both the visual images through early innovative bursts while encouraging deeper reflection in the authoring of accompanying text. Designers perform the early creative stages in their design by identifying options, then exploring and conceptualizing solutions—but the claims provide a basis for scientifically sound solution verification and production.

At this point, this work is taking steps to set the stage for design by reuse by assessing the benefits of incorporating creativity and rationale together. One future direction is to assess the quality of the designs that are produced as a result of the activity. Another future effort must explore how the process of brainstorming before storyboard construction can be improved through appropriate designer exposure to images and claims. Early exposure to images without rationale might inspire designers to interpret the images in very different ways, leading to a larger pool of possible insights. When designers are exposed to the associated rationale later, they may weigh the utility of their ideas against the recorded argumentation.

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SUPPORTING AWARENESS IN CREATIVE GROUP WORK BY EXPOSING DESIGN RATIONALE

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Abstract: *When creativity is taken as a long-term, complex, and collaborative activity, support for awareness is required for group members to monitor the development of ideas, track how these ideas became narrowed, and understand how alternatives are being implemented and integrated by colleagues. In this paper, we investigate the effects of exposing design rationale to convey awareness, specifically activity awareness, in group creativity. Through evaluating a prototype, we investigate status updates that convey design rationale, and to what consequences, in small groups in fully distributed collaboration. We found that status updates are used for a variety of purposes and that participants' comments on their collaborators' status updates provided feedback. Overall, results suggest that participants' awareness about their collaborators' future plans increased over time. Majority of participants found the status updates useful, particularly those with higher metacognitive knowledge. Based on our results, two design strategies for activity awareness are proposed.*

Keywords: *computer-supported awareness, status updates, metacognition, Facebook, Twitter.*

INTRODUCTION

A fairly typical form of creativity—and perhaps even more important than the isolated lightning bolt—is the relatively long-term and collaborative development of innovative ideas. Researchers have argued in prior work that computer-supported awareness is critical for successful collaborative work, as well as creative work (Farooq, Carroll, & Ganoë, 2007).

The concept of awareness in computer-supported cooperative work (CSCW) literature has taken many forms. For example, social awareness (Erickson & Kellogg, 1999) involves knowing who else is present in a shared workspace, while workspace awareness (Gutwin, Greenberg, & Roseman, 1996) conveys who is doing what in the sense of manipulating shared artifacts. For a detailed review of awareness in CSCW, refer to Schmidt (2002).

More recently, with the adoption of Web 2.0, new social networking media have emerged that incorporate novel ways of providing awareness of people's activities. For instance, Facebook, an on-line social networking site, allows friends to specify what they are doing through status updates. These status updates are broadcasted to one's friends. Twitter is yet another social networking medium that among many functions serves the purpose of keeping friends, family, and colleagues connected through the exchange of quick, frequent answers to one simple question: What are you doing right now?

The notion of providing status updates for informal, nonwork related purposes, such as in social networking media (e.g., Facebook, Twitter), seems to be anecdotally successful in supporting awareness. For example, Farooq et al. (2007) showed that different types of breakdowns in creativity do occur in distributed collaboration and can be supported by designing appropriate awareness mechanisms around status updates.

We thus are motivated to investigate the feasibility, effectiveness, and consequences of such status updates in the context of creative group work. In this paper, we describe a prototype for updating statuses in collaborative work. We report on a study of small groups using this prototype over an extended period of time to answer the exploratory research question: How can status updates be used in creative group work and with what consequences?

The outline of this paper is as follows. First, we conceptualize status updates as providing activity awareness in collaborative work. Second, we discuss how our contribution is situated in prior work on status updates in CSCW. Then, based on an existing empirical study, we describe the design of a status update prototype that provides activity awareness in collaborative work. Finally, we present an evaluation of the prototype. We conclude by suggesting implications of our results and future work.

EXPOSING DESIGN RATIONALE AS STATUS UPDATES TO SUPPORT ACTIVITY AWARENESS

We are investigating the provision of status updates to convey activity awareness in creative group work. *Activity awareness* is cognizance of other people's intentions, plans, priorities, and understandings with respect to an ongoing endeavor, of the criteria they will use to make decisions and evaluate joint outcomes, of the knowledge, skills, tools, and other resources they can contribute to a joint project, of the social networks they participate in, and of how they can engage others in the shared activity (Carroll, Neale, Isenhour, Rosson, & McCrickard, 2003; Carroll, Rosson, Convertino, & Ganoe, 2006).

By definition (Carroll et al., 2003; Carroll et al., 2006), activity awareness is more than a matter of registering the current state information. It transcends synchronous awareness of where a collaborator's cursor is pointing, where the collaborator is looking, and so forth. 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 to learn about developing circumstances and the initiatives, reactions, as well as sense making of other people with respect to ongoing and anticipated courses of action. It is continually negotiated, constructed, and enacted throughout the course of a collaborative interaction.

Currently, status updates in social networking media are employed to present general and often lighthearted self-disclosures (e.g., “Joe is glad the semester is over”; “Kathy is craving pizza”). However, one can imagine recruiting the mechanism of status updates for the purpose of supporting activity awareness in collaborative work; thus, a group member might post a status update such as, “Sam is finishing up Section 3 of the heuristic evaluation report.” In this application, a status update is specific and activity-oriented. Of course, this single status update is just an excerpt from a presumably more extensive signaling protocol but, even so, it reminds group members of the planning and negotiation that divided up report sections, and of the ensuing steps in the plan. It conveys something about Sam’s progress, and about what other group members may need to be doing in order to coordinate with Sam.

In the balance of this paper, we will refer to status updates that are intended to support activity awareness as *activity updates*. Our perspective on activity updates is that the updates actually constitute design rationale. Each team member keeps his/her partners apprised of that member’s activities and reactions through the updates. This puts the partners’ actions within the intentional context of what they are trying to do, how they assessed what others are trying to do, and so on. The updates are rationale-in-action, or *situated rationale*, as opposed to more typical case of rationale created after the fact to reconstruct or explain what happened.

RELATION TO PRIOR LITERATURE

Researchers in several CSCW studies have investigated the use of status updates in collaborative contexts. For example, Tickertape (Fitzpatrick, Parsowith, Segall, & Kaplan, 1998) is a lightweight awareness tool to facilitate social interaction between coworkers. The Notification Collage (Greenberg & Rounding, 2001) is a full-fledged groupware system that incorporates the notion of activity indicators through a variety of media, such as digital photos and video. The Community Bar (McEwan & Greenberg, 2005) extends the Notification Collage by supporting communities in fostering and maintaining ad hoc interaction.

Although there are some similar attributes between our structured activity updates prototype and other systems, there are also significant differences. Primarily, we are studying awareness of longer term activities as intentionally broadcasted by users in the context of fully distributed work, not social settings. For example, Smale and Greenberg (2005) studied status updates among instant messenger clients. Though their study context was not collaborative work, it is interesting to note that some of their communication categories of status updates are similar to ours. In their categorization scheme, “fun” is a type of status update that overlaps with our findings. Particular to our study context, Smale and Greenberg noted that people use status updates to broadcast information without involving chat conversation. This supports the feasibility of recruiting status updates for distributed collaborative work as a natural extrapolation from their original intended use in social networking media.

In their paper, Zhao and Rosson (2009) presented a complementary contribution to our work. They retrospectively investigated why people microblog and its potential impact on informal communication in work environments. Those authors suggested that microblogging may promote informal communication that complements other forms of interaction (e.g., IM, e-mail, phone, face-to-face).

Perhaps the work most related to ours is the study by Rittenbruch, Viller, and Mansfield (2007). In presenting their model of intentionally enriched awareness, Rittenbruch et al. reviewed and critiqued prior accounts of awareness as ignoring the ways that actors deliberately present themselves and their activity to collaborators. Rittenbruch et al. located intentionally enriched awareness as lying between mere perception of appearances and events and the public communication and explanation of one's activity.

Rittenbruch et al. (2007) focused on notifications of interest and availability for specific activities, such as playing a computer game or going for a coffee. They developed a tool to configure activity-specific polling and notification, enabling users not only to signal their own availability and interest, but to coordinate carrying out the activity with other like-minded users. This tool was used by users who were colocated. Rittenbruch et al. categorized the status notifications as activity indicators and activity inducements. Activity indicator notifications act as invitations to announce that certain activities are about to commence and that fellow users are invited to jointly participate. Activity inducement notifications are statements to convey that people are already engaged in activities.

DESIGN OF ACTIVITY UPDATES

The empirical study that we report in this paper addresses our overall research question, which we restate as, how can activity updates be used in creative group work and with what consequences? We evaluated a prototype that supports status updates in the context of collaborative work by conveying activity awareness. The design of our prototype is based on the Farooq et al. (2007) study.

Activity Updates as Structured Templates

Farooq et al. (2007) conducted an empirical study of small groups collaborating on a long-term, creative task in a distributed setting. The researchers concluded that members in distributed groups lacked activity awareness that would otherwise be critical not just for successful but also creative collaboration. A design implication emerging from this study was the notion of structured activity updates, whereby team members can enter status updates using predefined activity-centric templates that relate to their current work. An example of a structured activity update would be to allow Sam to fill in the blanks in the following activity-centric template: "Sam is planning to _____." The activity updates are structured in the sense that each group member is presented with a template to update his/her status.

Whereas social networking sites allow users to enter any type of informational update, our proposed updates are activity-centric, that is, they relate to the collaborators' task at hand. By structuring the updates in predefined activity-centric templates, we believe users will be more inclined to think in terms of what they are doing with respect to their immediate task and less inclined to socially loaf and focus on nonwork-related self-disclosures. This is consistent with Malone, Grant, Lai, Rao, and Rosenblitt's (1986) finding that semistructured messages can simplify designing systems that (a) help people formulate information they wish to communicate, (b) automatically select, classify, and prioritize information people

receive, (c) automatically respond to certain kinds of information, and (d) suggest actions people may wish to take upon receiving certain other kinds of information.

A structured approach to activity updates has its associated trade-offs. For instance, entering activity updates may be too constraining and become an impediment in the users' workflow and creative process. While acknowledging this trade-off, our rationale for keeping the activity updates structured was specifically to make it convenient for users to quickly select from a predefined list of activity templates, rather than ruminating over the nature of their activities.

Types of Activity Updates

Given the rationale for making activity updates structured, the next step was to identify the types of activity updates. We followed an empirical approach to achieve this goal. Based on the data collected from Farooq et al.'s (2007) study, we analyzed the chat communication transcripts to identify the different types of activities that collaborators expressed and shared. The primary researcher in this paper read and reread each chat communication transcript to identify recurring themes related to activities that group members were engaged in consistently. These 10 types of activities were then discussed and revalidated with two other researchers engaged in the project. Ten distinct types of activities were identified that would serve as templates for group members to update their status: planning, brainstorming, working, asking, suggesting, summarizing, dividing up work, proofreading, agreeing, disagreeing.

A trade-off to empirically identifying the types of activity updates was that the 10 types conveyed activity self-disclosures at different levels of detail and generality. For instance, *working* is a relatively broad activity compared to, say, *proofreading*, which is a very specific activity. We decided not to tweak these empirically based activities (e.g., relabel the activities at a similar level of detail) since, as a secondary research question, it may be interesting to understand how users update activities that vary in granularity. Further, because the 10 activity types emerged from a prior study, we took them as first-order, validated approximations to the kinds of activities group members would be engaged in.

Prototype

Based on our analysis, we designed and developed a prototype for structured activity updates (Figure 1). The structured activity updates prototype can be divided into three sections.

In Section 1 (Update Your Activity), users can choose from among the 10 activity templates and fill in the blanks to share their activities. The 10 activity types were presented in random order. After a user fills in the blank and presses the Update Activity button, the activity updates are displayed in Section 2 of the prototype. In addition to the team's most recent updates, each user's prior activity update is also displayed. We thought that providing a user's previous activity would be useful in contextualizing the current activity.

Section 3 of the prototype provides a mechanism for users to comment on group members' activity updates. Our design rationale was that activity updates could instigate and provoke users to reflect on and possibly respond to group members' activities. By commenting on others' activities, group members could provide feedback and possibly engage in a discourse. For instance, in Section 3, Patti commented on Michael's activity update, which led Kristin to agree with Patti's comment.

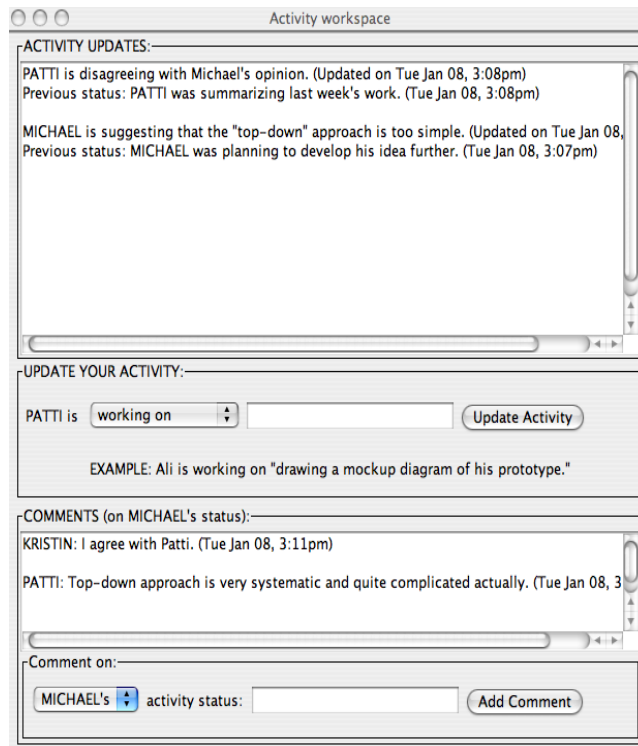


Figure 1. Structured activity updates prototype.

EXPERIMENTAL STUDY

We conducted an empirical study to investigate the use and consequences of structured activity updates. The context was similar to that of Farooq et al.'s (2007) study, where small groups collaborated on a long-term, creative task in a distributed setting.

Research Questions

To answer our overall research question, we formulated specific questions in the following two categories: use of structured activity updates (USE) and consequences of structured activity updates (CONSQ). In the former category (USE), we present results that answer the following three questions:

- USE1: How frequently were the different types of activity updates used?
- USE2: For what purposes were the activity updates used?
- USE3: For what purposes were the activity comments used?

USE1 helps to distill any significant differences in the usage among the 10 types of structured activity updates. USE2 and USE3 help in understanding the different ways in which activity updates and comments were used.

In the CONSQ category, we present results that answer the following three questions:

- CONSQ1: Did users find the activity updates useful?

CONSQ2: Did the activity updates increase awareness over time?

CONSQ3: Did metacognition affect users' perception of the usefulness of activity updates?

CONSQ1 directly answers the question of whether or not the activity updates were useful. CONSQ2 is motivated by the fact that we ultimately are interested in whether or not activity updates had a significant effect on users' awareness over time. We expected that activity updates would enhance awareness. CONSQ3 is motivated by a prior study on activity awareness (Convertino, Neale, Hobby, Carroll, & Rosson, 2004), which provided preliminary evidence that people's metacognitive abilities can affect the extent to which they become aware. Whereas cognition is the act of knowing, metacognition is the ability to reflect upon, understand, and control that knowledge (Schraw & Dennison, 1994). Metacognition has also been noted as the awareness and control over one's thinking (Brown, Bransford, Ferrara, & Campione, 1983; Flavell, 1978; Metcalfe & Shimamura, 1994). We expected that people with lower metacognition would find the activity updates more useful than those with higher metacognition because the tool would compensate for their lower metacognitive abilities.

Participants

Participants in the study comprised 49 undergraduate students enrolled in an introductory course on HCI at a large university. A total of 13 groups were randomly assigned. Ten groups comprised 4 students each and three groups comprised 3 students each. All groups had no history of working together but were familiar with status updates, particularly with Facebook.

Task Details

Each group was instructed to write a formal report exploring design enhancements to Angel, which is the university's course management system that all students must use. The report was to cover functional requirements to enhance the design of Angel's user interface, accompanied with scenarios and storyboards that illustrate the functional requirements. This task was modeled on previously documented tasks (Ocker, Hiltz, Turoff, & Fjermestad, 1996; Olson, Olson, Storosten, & Carter, 1993) used in distributed collaboration. The instructions emphasized that group members were allowed only to collaborate virtually using the designated shared workspace.

Tools

Group members worked on the collaborative task in a shared workspace called BRIDGE (Ganoë et al., 2003). BRIDGE supports both synchronous and asynchronous collaboration. The BRIDGE Java-based client (Figure 2) supports shared editing of documents through replicated objects. Replicated objects are objects that are retrieved by multiple collaborating sessions and whose state is kept synchronized on all clients and the server when any replica is changed. Examples of collaborative tools that were provided in BRIDGE included a persistent chat tool, wiki-based text documents, and drawing editor. The structured activity updates prototype was also provided.

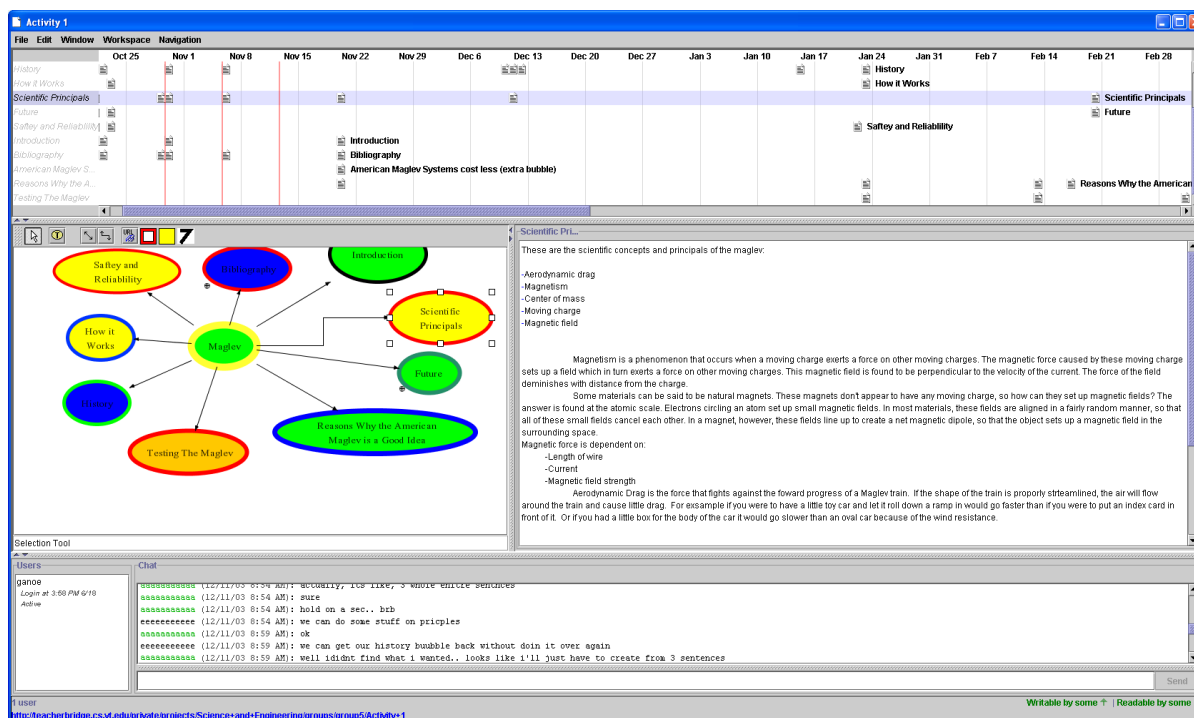


Figure 2. BRIDGE: Basic Resources for Integrated Distributed Group Environments.

Procedure

All students consented to participate in the experiment. Prior to the experiment, all participants were trained to use BRIDGE. Two in-class sessions, approximately 20 minutes each, were used for training. Training included using the structured activity updates.

The duration of the experiment was two and a half weeks. Participants collaborated synchronously and asynchronously. Five in-class sessions were used for synchronous collaboration, each lasting approximately 20 minutes. The participants also collaborated on-line in out-of-class sessions between each of the in-class synchronous sessions. Participants worked in a distributed fashion; the instructor ensured this for the in-class sessions. For out-of-class sessions, we analyzed the chat transcripts for any indicators of face-to-face collaboration (e.g., if one member referred to a face-to-face meeting); we did not find any such indicators.

Because we were interested in studying the use and consequences of the structured activity updates prototype, participants were reminded to update their activity status. Participants were not compensated for or graded on using the structured activity updates prototype.

Following is a typical scenario of interaction. During an in-class session, “Ben” communicates with his two group members about what Angel’s user interface lacks by using the chat tool. While chatting, Ben uses the structured activity updates prototype to change his status to “Ben is brainstorming how Angel can be enhanced” to make his group members cognizant of what he is doing. Ben records a few user interface enhancements in a wiki-based text document. Logging into BRIDGE at night during an out-of-class session, Ben changes his status to “Ben is asking his group members to read his enhancements and provide feedback.” In

the next in-class session, Ben notices that both his group members have commented on his status and have improved upon his ideas.

Data Collection

When the participants consented at the start of the experiment, we collected background data, such as demographic information. For metacognitive abilities, a previously validated 52-item scale (Kumar, 1998) was used.

During the experiment, all interactions in BRIDGE were logged onto the server. For example, communication messages in the chat log and changes to shared data were recorded with time stamps. All activity updates and comments on activity updates were recorded over time.

After each of the five synchronous in-class sessions, participants answered the following statements on a Likert scale of 1 (*strongly disagree*) to 9 (*strongly agree*) related to their level of awareness (LA). These assessments have been previously validated by Convertino et al. (2004):

LA1: I know what my group members have worked on so far.

LA2: I know what my group members will work on next time.

LA3: I could tell what my group members were working on while we were collaborating synchronously.

LA4: I could tell what my group members were working on while we were collaborating asynchronously.

LA5: I found it difficult to tell what work my group members had done after being absent from my team workspace for at least a day.

LA4 and LA5 were not administered following the first synchronous in-class session since the groups had no history of working together on the task. LA2 was not administered after the fifth synchronous in-class session since it was the final group interaction.

After the experiment, participants were asked the following question in relation to the usefulness of the structured activity updates (SAU) prototype: Was the structured activity updates useful? If yes, how was it useful; provide an example.

RESULTS

Below, we present our results in relation to the six specific research questions (USE and CONSQ) we posed earlier. Each result is followed by a brief discussion.

USE1: How Frequently Were the Different Types of Activity Updates Used?

For each of the 49 participants, we counted the frequency of using each of the 10 activity updates. We also categorized the frequency by synchronous (in-class sessions) and asynchronous (out-of-class sessions) modes of communication. Activity updates were used a total of 511 times, with nearly half split across synchronous (252) and asynchronous (259) updates. These frequencies are summarized in Table 1.

Table 1. Frequency of Activity Updates.

Activity type	Total	Sync	Async
Working	170	67	103
Planning	99	54	45
Brainstorming	76	62	14
Proofreading	62	9	53
Agreeing	39	26	13
Suggesting	23	15	8
Asking	20	7	13
Summarizing	10	4	6
Disagreeing	6	4	2
Dividing up work	6	4	2

We ran a repeated-measures ANOVA to compute any statistically significant differences between the frequencies of the different types of activity updates. The analysis for unequal variances revealed that there were significant differences in the frequencies between the 10 types of activities, $F(1, 48) = 43.071$, $p < 0.001$, though this was a moderate effect size (eta-squared = 0.473). Pairwise comparisons for the top four activities revealed that the mean frequency of Working was significantly higher than all other types of activity updates; Planning was significantly different from all except Brainstorming; Brainstorming was significantly different than all except Planning and Proofreading; and Proofreading was significantly different than all except Brainstorming. A similar analysis could not be run against synchronous and asynchronous modes of communication due to sparse data. From Table 1, however, it is apparent that in the synchronous mode of communication, the three most frequently used activities in rank order were Working, Brainstorming, and Planning; in the asynchronous mode of communication, the three most frequently used activities were Working, Proofreading, and Planning.

Discussion. Working was the most frequently used activity update, for which there could be several reasons. Because the structured activity updates prototype was meant to provide activity awareness in the context of work, it seems natural that collaborators would be inclined to select the Working activity to make others aware of their work-related tasks. It is also possible that Working was the type of activity that collaborators most frequently engaged in. The most plausible explanation is that Working is a general adjective that seems to encompass some if not all of the other types of activities, which are more specific in their description. It seems to be the case that semantic granularity plays a vital role in selecting activity updates, a point that we return to toward the end of the paper.

There was also a disparity in frequencies between the synchronous and asynchronous modes of communication. Two activities particularly stand out. Brainstorming was skewed toward the synchronous mode of communication while Proofreading was skewed toward the asynchronous mode of communication. This is not a surprise. Brainstorming is typically a synchronous activity and proofreading is typically an asynchronous activity.

USE2: For What Purposes Were the Activity Updates Used?

Based on the postexperiment questions (SAU1 and SAU2), we analyzed the responses using qualitative analysis. All 49 participants responded to both questions. We coded the 98 responses with the goal of identifying the different purposes that the activity updates were used for.

A total of 37 distinct phrases were identified as specifying a purpose and thus were open coded (Strauss & Corbin, 1998). A total of nine codes emerged from the data that represent different purposes for how the activity updates were used. These purposes are listed in Table 2 with a coded phrase (user quote) that illustrates the purpose.

Discussion. The qualitative analysis reveals that activity updates were used in varying ways. Broadcasting one's activity and staying up to date of what one's group members are doing were expected ways of how activity updates would be used. This is similar to how status updates are used in social networking media. However, activity updates also seemed to be used for coordinating work and task dependencies, understanding group progress cumulatively over time, and tracking group member contributions.

USE3: For What Purposes Were the Activity Comments Used?

The actual comments that users expressed in the structured activity updates prototype were analyzed using qualitative analysis. We coded all of the comments with the goal of identifying the different purposes that they expressed.

We open coded the comments at the group level of analysis for each of the 13 groups so as to understand any dependencies among group members that the comments were referring to.

Table 2. Different Ways That Activity Updates Were Used.

Purpose of activity	No. of phrases	Data example
Group member update	13	"Gave a little info on what each member was doing."
Status broadcast	8	"To show my team members what part of the project I was currently working on."
Asynchronous communication	4	"Allowed me to see what each member of my group was working on while I was not logged on."
Group progress	4	"Informed me about my group's progress."
Group member login	2	"I could see who logged in last."
Synchronous communication	2	"When different tasks were going on simultaneously, it was helpful to know who was doing what."
Task coordination	2	"I logged on to finish scenario 1, and saw what other work was necessary."
Member login frequency	1	"Showed how often group members were logging in and making additions."
Timeline	1	"It was helpful as a timeline."

A total of eight codes emerged from the data that represent different purposes for how the comments were used. These purposes are listed in Table 3, accompanied with the following information: the number of groups (No. of groups) that incorporated the particular purpose and the number of phrases (No. of phrases) that were coded.

Feedback was the most frequent purpose for a comment where participants provided feedback to group members, such as, *“Nice job of organizing the list.”* The comments were also heavily used by all groups to coordinate work (e.g., *“We will review each other’s sections on Wed.”*), although we distinguish this from Elaboration, which refers to an explication or enhancement of an idea (e.g., *“We should come up with a few more asynchronous ideas!”*).

Twelve of the 13 groups moderately used the comments to encourage and support each other (e.g., *“Keep up the good work”*). In nine groups, we noticed that the comments represented a communication discourse similar to a conversation that could have occurred using the chat tool. For example, Greg commented on Katie’s status: *“Can you think of any more functional requirements?”*; a few hours later, Ed also commented on Katie’s status by following up on Greg’s message: *“I’m also trying to figure out some more functional requirements.”*

A small number of comments were used to remind group members of deadlines or responsibilities (e.g., *“Make sure to add your pros and cons”*). A small number of comments were also used for nonwork or “fun” purposes (e.g., *“I also like surfing”*) and to reflect on social dynamics during the metamorphosis stage of concluding group work (e.g., *“I have enjoyed working with you and the other group members on this project”*).

Discussion. The qualitative analysis reveals that comments were used in varying ways to support unplanned, brief, and ad hoc communication. The comment feature in the structured activity updates prototype was used not only for the obvious purpose of providing feedback to group members but also served as a secondary mechanism or communication backchannel (Ackerman, 2000) to allow group members to coordinate work, encourage and remind each other, and occasionally discuss nonwork topics. Such casual interactions keep individuals informed about each other in social and professional contexts, reinforce social bonds, and make the transition to tightly coupled collaboration easier (Whittaker, Frolich, & Daly-Jones, 1994).

Table 3. Different Ways That Activity Comments Were Used.

Purpose of comment	No. of groups	No. of phrases
Feedback	13	292
Coordination	13	55
Encouragement	12	41
Elaboration	11	28
Discourse	9	21
Reminder	7	16
Fun	5	19
Metamorphosis	2	5

CONSQ1: Did Users Find the Activity Updates Useful?

In the postexperiment question (SAU1), we asked participants whether or not they found the structured activity updates prototype useful. Of the 49 participants, 22 (45%) found the prototype useful, 9 (18%) found it somewhat useful, and 18 (37%) did not find the prototype useful.

Some of the participants expanded on why the structured activity updates prototype was not useful. They expressed that the chat communication tool in BRIDGE served the purpose that was intended by the structured activity updates prototype. Among such responses were the following typical user quotes: “*We communicated what we were doing through the chat function*”; “*This could have automatically been extracted from a chat and displayed*”; “*I could just go into the chat logs and find out the specific task of each person.*”

Discussion. There were mixed feelings toward the usefulness of the structured activity updates prototype. Our prior research question (USE2) provides strong evidence that participants used the prototype in varying ways. Directly asking participants about the usefulness of the prototype did not solicit an overwhelming positive response. This may be attributed to the fact that the structured activity updates prototype was not integrated with the chat communication tool. Hence, the design required collaborators to expend extra effort to switch between the structured activity updates prototype and the chat communication tool in order to make effective use of both. Many participants who did not find the prototype useful acknowledged this design shortcoming.

CONSQ2: Did the Activity Updates Increase Awareness Over Time?

We ran a repeated-measures ANOVA to compute any statistically significant differences on each of the five awareness questions (LA1-LA5) over time. There was increased awareness over time for LA2 over the final four in-class sessions: $F(1, 44) = 13.71, p < .001$ (eta-squared = 0.238). There were no significant differences in the mean rating for LA1, LA3, LA4, or LA5 over time.

Discussion. The result for LA2 implies that the structured activity updates informed group members what their collaborators will work on in the future. This seems to make sense since, in highly interdependent and collaborative tasks, group members require a greater amount of planning to understand what everyone is going to do. LA1, LA3, LA4, and LA5 dealt with understanding what group members already did. The persistent BRIDGE workspace seemed to have provided enough awareness of such an understanding. However, the workspace cannot provide an understanding of what collaborators are going to do next unless such an understanding is externalized by the group members themselves. Such was the case as group members used the structured activity updates to make their collaborators cognizant of what they are going to do.

CONSQ3: Did Metacognition Affect Users’ Perception of the Usefulness of Activity Updates?

We conducted a reliability analysis for the 49 responses to the 52-item metacognition questionnaire. The analysis revealed a high value of reliability (Cronbach’s alpha = 0.984). We then separated the 49 participants into two categories based on their responses of whether

they found the structured activity updates prototype useful or not. Thus, we had 31 participants in the “useful” category and 18 participants in the “not useful” category.

We ran a two-sample *t*-test between the two categories of usefulness (useful, not useful) with metacognition as the dependent variable. The analysis for equal variances revealed no statistically significant difference: $t(47) = -1.53, p = 0.133$.

The 52 items in the metacognition questionnaire were then loaded on two factors based on Kumar (1998): metacognitive regulation and metacognitive knowledge. Metacognitive regulation denotes planning, information management, monitoring, debugging, and evaluation. Metacognitive knowledge denotes declarative, procedural, and conditional knowledge. The above two-sample *t*-test for metacognitive regulation as the dependent variable revealed no statistically significant difference: $t(47) = -0.875, p = 0.386$. The same two-sample *t*-test for metacognitive knowledge as the dependent variable revealed a statistically significant difference: $t(47) = -2.137, p < 0.05$. The mean metacognitive knowledge rating for participants who found the structured activity updates prototype useful ($M = 58.76$) was significantly higher than the participants who did not find the prototype useful ($M = 53.92$).

Discussion. The result that participants with higher metacognitive knowledge found the structured activity updates prototype more useful than those with lower metacognitive knowledge seems counterintuitive. One would expect that the prototype would compensate for lower levels of metacognition and thus be more useful to such participants.

According to Flavell (1979), metacognitive knowledge refers to acquired knowledge about cognitive processes, knowledge that can be used to control cognitive processes, as well as knowledge of one’s own learning processes. For example, a person may be aware that study session efforts will be more productive in the early morning when everyone is asleep rather than evening when there are many distractions. In this sense, participants with higher levels of metacognitive knowledge can be opportunistic in identifying and leveraging strategies that can help them monitor their progress. In such cases, participants are using their conditional knowledge about when and where it is appropriate to use strategies or, in our case, awareness tools, to enhance their collaborative learning experience. Such an explanation would lend support for our result.

On the other hand, metacognitive regulation implies checking the outcomes of incorporating strategies and ensuring that cognitive goals have been met. In this sense, our prototype did not explicitly support a cognitive goal or outcome but rather the process of reaching a particular goal or outcome. The result that there was no significant difference in the levels of metacognitive regulation would be corroborated by such an explanation.

IMPLICATIONS FOR ACTIVITY AWARENESS

In this paper, we started by posing an exploratory research question: How can activity updates be used in collaborative work and with what consequences? Our study suggests that activity updates—a way of providing activity awareness—can be used for several purposes, increasing awareness of what collaborators will do next over time. Further, activity comments seemed to provide an effective communication backchannel to support ephemeral and infrequent collaboration that is contextually dependent on the activity updates. The results also suggest that users with higher levels of metacognitive knowledge perceive activity updates as more useful

than users with lower levels of metacognitive knowledge. In this section, we discuss implications of our results by reflecting on two design strategies for providing activity awareness.

Activity Awareness Can Support Lightweight, Informal Self-disclosures Through Communication Backchannels

Though the participants were provided with a formal, primary communication channel (chat), the majority of them found activity updates and comments useful during their collaboration. We argue that communication backchannels that allow the expression of lightweight, informal self-disclosures in work contexts can be an effective way to increase activity awareness, particularly to apprise each other of their future cognition.

From previous work in CSCW in work contexts, we know that it is important to provide a communication backchannel. Our study characterizes one type of communication that this backchannel should support, namely, lighthearted and casual meta-activity information. Typical communication backchannels usually demand social responsiveness. For instance, during video conferencing, chat may be used as a backchannel to complement verbal communication. In such a scenario, group members are expected to oblige chat entries and respond in kind. On the other hand, activity updates are an example of an informal communication mechanism, where group members are merely expressing their thoughts on a task that may or may not warrant further explication or response. In this way, activity updates are a lightweight mechanism to express informal activity-related information that has a formal bearing on the group's primary task. Our results suggest that activity updates did indeed provide activity awareness through lightweight, informal self-disclosures, as they were primarily used to update group members of one's progress. Further, comments provided an additional layer of backchannel communication to express feedback on other's work progress over time.

Our design strategy—the provision of activity awareness through lightweight, informal self-disclosures to enrich formal communication mechanisms such as chat—strengthens prior results. In Rittenbruch et al.'s (2007) study, it was discovered that notification and communication are interleaved processes. Our study extrapolates Rittenbruch et al.'s result by implying that activity updates are appropriate to express through notification mechanisms.

The different purposes for which the activity updates were used in our study are much broader and deeper than the two general categorizations of activity indicators or activity notifications as identified by Rittenbruch et al. (2007). For example, we identified nine different ways of how activity updates were used. Because our prototype incorporated the notion of structured activity updates using predefined templates, we were able to explore details of how users coordinated specific types of activities. Further, the activity comments feature was encouraging to the effect of acting as a communication backchannel in distributed work contexts. Our study also raises deeper, theoretical issues of how awareness is related to people's metacognitive abilities, a connection that has not been studied in the above-mentioned literature.

Activity Awareness Can Engage Users at a Metacognitive Level

The dominant approach in CSCW has been to conceptualize awareness mechanisms as engaging users at a cognitive level by making them aware of system-based, event-driven information. For example, knowing where a collaborator's mouse is pointing can indeed

facilitate the immediate coordination of manipulating shared artifacts. Such awareness mechanisms rely on detecting and providing short-term informational states for low-level tasks and subtasks that facilitates users' immediate cognitive goals. Although the provision of such system-based, event-driven information is critical, it is limited to the extent of what people need to, and can be, aware of. Indeed, awareness mechanisms cannot detect and convey people's intentions. In his critique of awareness being construed as a passive process (Dourish, 1997), Schmidt (2002) said that passive awareness is restrictive and it prevents users from engaging in practices to align and integrate their distributed but interdependent activities. Rittenbruch et al. (2007) capitalized on this notion to argue for a more intentionally enriched awareness mechanism where users can explicitly characterize and share their own activities.

In this sense, we argue that activity awareness mechanisms should engage users metacognitively. Activity awareness mechanisms should seek to help users regulate their cognition and think explicitly about their design rationale with respect to learning and work goals. By explicitly characterizing and sharing their activity intentions and rationale, users can engage in and think about deeper work-related interactions such as coordinating responsibilities, managing dependencies, resolving conflicts, and so forth. This allows collaborators to be cognizant of each other at the level of activities, a higher-order function of shorter and immediate tasks and subtasks that are merely system-based, event-driven nuggets of information. This design strategy is consistent with our result that, in general, metacognition plays a role in determining the usefulness of awareness mechanisms. Specifically, people with higher metacognitive knowledge seem to be more strongly oriented toward and are interested in being aware of their collaborators' activity. It follows from this result that capitalizing on and effectively using activity awareness mechanisms may also be a metacognitive strategy. This suggests that, in general, awareness mechanisms should not be limited just to system-based, event-driven information of what is currently going on in a shared workspace, but also that awareness should be about providing cognizance of activities that need to be internalized and monitored over time such that users are prompted to strategically regulate their cognition and manage their knowledge in order to better achieve their overall goals collaboratively.

DISCUSSION AND FUTURE WORK

As discussed in our results, it is likely that the semantic granularity of the activity types matters. The variability in use of the 10 activity types provides some evidence of this. Many issues are raised due to our design choice. For example, did all participants take the 10 activity types to mean the same thing? How does the frequency of engaging in a specific activity affect the selection of different activity types? Perhaps most importantly, can circumstances be identified where more general activity types are preferred over more specific activity types, and vice versa? Further studies are required to address these issues comprehensively.

Another important question raised by our study is the design choice of structuring the activity updates. Though participants were not asked to comment on this issue, it seems important to reflect on the level of structure imposed by the predefined activity templates. A system that resembles our design choice of structuring the activity updates is the Coordinator (Winograd & Flores, 1986), a large-scale electronic communication system that enlists participants in a coding procedure by using predefined speech acts aimed at making implicit

intent explicit. The premise of this procedure was that explicitly identified speech acts are clear, unambiguous, and preferred, because people tend to be vague regarding their own intent and that of others (Suchman, 1994). Though the Coordinator was largely cited as a failure, it remains to be empirically determined if structured activity updates are preferred over unstructured activity updates and under what circumstances.

Another interesting area to explore is the relation between activity updates and the design artifact and process. Our study's scope did not include whether or not activity updates helped interpret the design rationale that shaped the artifact. Essentially, such an exploration could help answer whether activity updates change the design process or quality of the outcome. More interestingly, the relation between metacognition and design rationale could be understood. If one adopts the perspective that design rationale is essentially metacognition about design, subsequent studies can be designed to assess the effects of metacognitive processes on design outcomes.

Our result that activity updates were used in a variety of ways is encouraging in further exploring the generative nature of the predefined activity types. We provided 10 activity types, or speech acts (as in the Coordinator). Investigating a broader range of speech acts that continually emerge from the ground up is a research issue worthy of exploration. Some participants who did not find the activity updates useful strongly suggested that these be identified from their chat entries. For example, collaborative filtering mechanisms can be used to extract activity updates automatically that can then be fine-tuned by users. Unlike our design choice, if the activity types are not limited and are allowed to grow over time, these activity types can be suggested to users by recommender systems. Our result that some activity types are used differently during synchronous versus asynchronous communication can be extrapolated to recommend certain activity types, depending on the type of communication users are engaged in. Other attributes in addition to communication type, such as duration of a work session (e.g., short spurt vs. extended period) or the stage at which a group is operating (e.g., divergent vs. convergent thinking), can be also mined to recommend appropriate activity updates.

One limitation of our study was that the participants were undergraduate students, although such a shortcoming is to be expected in controlled settings that pool a large number of experimental subjects. We plan to conduct a field study where participants of a distributed research group are collaborating on a project over several weeks. Such a study would allow us to investigate our results further in a naturalistic setting.

Our general empirical finding that metacognitive abilities affect perceived usefulness of awareness mechanisms should be investigated further. Our finding is based on one study and is limited to one factor of metacognition (metacognitive knowledge). We plan to study how and when metacognition, and both factors of metacognitive regulation and metacognitive knowledge, have an effect on awareness and whether this effect can be controlled. We encourage designers and researchers interested in supporting awareness to incorporate metacognition as a variable in their user studies.

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MINING CREATIVITY RESEARCH TO INFORM DESIGN RATIONALE IN OPEN SOURCE COMMUNITIES

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Abstract: *Design rationale can act as a creativity support tool. Recent findings from the field of creativity research present new opportunities that can guide the implementation and evaluation of design rationale's ability to foster creative processes and outcomes. By encouraging the exploration of failure through use of analogy, design rationale can foster creative transfer and enable progress in new directions. Open source communities offer an opportunity to observe a form of intrinsically motivated ad hoc design rationale, exhibiting formal and informal information transfer links within forums and allowing access to common tools, expertise, and mentorship. A discussion of a spectrum of implementations of design rationale informs strategies to mitigate conflicts and advance inherent synergies between design rationale and creativity.*

Keywords: *design rationale, creativity research, creativity support tools, open source communities.*

INTRODUCTION

The 2003 National Research Council's (NRC) *Beyond Productivity* report examined elements of creativity and the emergence of human–computer interaction in everyday life, emphasizing a need for information technology (IT) to support creativity across domains (Mitchell, Inouye, Blumenthal, & the NRC 2003). It was proposed that adoption of improved tools that support creativity using IT backbones would yield economic and cultural benefits. Since then, available technology has matured even further, making creativity support easier and more productive. The NRC report also acknowledged that today's IT user has needs that go beyond traditional requirements for productivity and efficiency. IT has enabled today's user to join and contribute to new communities with ease, and to engage in creative acts on an everyday basis. These users, collectively engaged in creation, production, and distribution, demand that technologies work

with them, engage them, and keep them motivated. They thrive on competition and feedback from peers. They are socially embedded through IT networks, seek community-level knowledge sources, and revel in collaborative work. These new generations of users and developers are, in short, mature users of technology.

A complementary report by the Computing Research Association (2002) outlined five grand challenges of computer science and information science, including the challenges of creating opportunities for personalized learning, “a teacher for every learner,” and using hybrid teams of humans and software/hardware system technologies to create a team of one’s own (p. 5). By interacting with individuals and teams to enhance design rationale, these systems act as support tools. When used to support creativity, these software agents are considered to be creativity research tools. Systems that allow teams of software agents and humans to collaborate present an opportunity to use design rationale as a creativity support tool, modulating and communicating process and outcome.

Open source communities present an environment in which users and developers can take advantage of design rationale to support creativity. Open source simply means software whose source code is freely available for modification and reuse, in contrast to the commercial model of software that restricts access to source code to a firm’s employees and contractors. The open source paradigm has given rise to new organizational structures and practices, allowed for distributed community management of software, and promoted collaboration among participants. Open source’s mass involvement of highly skilled, intrinsically motivated participants creates an optimal environment to examine techniques to support creativity and employ design rationale.

In this paper, we discuss the use of design rationale as a creativity support tool in the context of the open source paradigm. The goal of advancing creativity in software design environments faces at least two issues. First creativity and new opportunities for creativity must be appreciated within the ongoing cognitive activity that occurs among software developers. Second, a suitable framework that supports articulation of these creative processes must be developed and used to enhance the processes and products of programming. As Hanson, a principal research scientist at MIT cited in von Hippel (2005), stated,

Creative programming takes time, and careful attention to the details. Programming is all about expressing intent and in any large program there are many areas in which the programmer’s intent is unclear. Clarification requires insight, and acquiring insight is the primary creative act in programming. But insight takes time and often requires extensive conversation with one’s peers. (p. 124)

Understanding the ways in which the elements of time, attention to detail, expressing intent, clarity, insight, and deep and persistent conversation manifest within the structure, process, and success of open source communities can elucidate ways in which design rationale contributes to creative programming.

As the design community grapples with its understanding of the relationship between design rationale and creativity (Carroll, 2010), an exploration of the question, “How can design rationale support creative processes and outcomes?” might allow fuller realization of design rationale’s potential. To address this question we will turn to the many possible implementations of design rationale, and the effect that each of them may have on creativity. First, we must ask ourselves how well design rationale plays the role of a creativity support tool, and what strategies can be

employed to enhance its efficacy. To understand this in terms of the context of the open source paradigm and the role of creativity in open source communities, we must understand the functions and roles of creativity support tools. Likewise, we must understand what creativity research tells us about the best practices for supporting creativity. This will include wider discussion of the consensual assessment of creativity (Amabile, 1983) and the role of transdisciplinary collaboration and metacreativity (Buchanan, 2001). We ground this discussion in the evolving nature of human–computer interaction and the opportunities for design rationale to support creativity when design activity spans disciplines, as is seen in hybrid software/hardware development, and process and product development in open source and do-it-yourself communities (Kuznetsov & Paulos, 2010; von Hippel, 2005).

DESIGN RATIONALE

Moran and Carroll (1996) defined design as “the process of creating tangible artifacts to meet intangible human needs” (p. 2). They stated that design seeks to fill the stated and unstated needs of the end user by bridging the gap between requirements and end product. A typical lifecycle of a design project bridges this gap with six phases: the requirement phase, design phase, building phase, deployment phase, maintenance phase, and redesign phase. In some respects, this is similar to models of software development life cycles. In both, design rationale plays an important role because, in practice, these phases and cycles are usually not strictly delineated. The iteration and complexity of their interconnection adds richness and depth to design projects.

Several definitions of design rationale exist, but Moran and Carroll (1996) defined six broad ways in which the term is used. Fundamentally, it is an “expression of relationship between a designed artifact, its purpose, the designer’s conceptualization, and the contextual restraints on realizing the purpose” (p. 8). Design rationale could be (a) logical reasons given to justify a designed artifact, (b) a notation for the reasons, (c) a method by which reasons for the design are made explicit, (d) documentation of reasons for the design, (e) steps for the design, or (f) the history of the design and its context. It provides an explanation of why a designed artifact is manifest in the manner that it is. Overall, “design rationale is concerned with systemizing the design process—its tools, techniques, methods, and management—for artifacts and their specifications” (Moran & Carroll, 1996, p. 8).

Fischer, Lemke, McCall, and Morch (1991) stated that the benefits of using design rationale are support for the maintenance and redesign of an artifact, reuse of design knowledge, and critical reflection. MacLean, Young, Bellotti, and Moran (1996) stated that design rationale aids reasoning and communication. Moreover, design rationale can encompass several tasks (MacLean et al., 1996), including documentation, understanding, debugging, verification, analysis, explanation, modification, and automation (Moran & Carroll, 1996). From these perspectives it becomes apparent that design rationale is meant as an explicit effort to promote deeper understanding of the design process and decision making, and to transfer this knowledge within the design team and community. Multiple facets of design rationale have emerged to facilitate and enhance the design process. The question at hand, then, is whether design rationale can be implemented in ways that promote creativity. To address this question, we will explore different implementations of design rationale in terms of their granularity and formality, instantiation, and scale.

Granularity and Formality

Implementation techniques can vary across a range of granularities. Fine-grained approaches detail every step and decision in the process, while coarse-grained methods take a broader, macrolevel view of documentation. Fine-grained design rationale is frequently time-consuming and can be burdensome and disruptive to designers and programmers and their creative processes. Coarse-grained design rationale runs the risk of missing significant events.

Design rationale can also be implemented across a range of formalities. Formal techniques usually track a prespecified set of concepts and categories, but may not fully represent every aspect of design processes. These communication tools can act as accessories to design process deliberation; however it is generally understood that even the most advanced capture tools will fail to completely record all underlying decisions and meanings (Gruber & Russell, 1996). This is particularly true when a new audience accesses the recorded design rationale, since the new users' backgrounds, assumptions, and even working vocabulary may have shifted significantly. More positively, formal processes can encourage deliberative processes, reflection, self-explanation, and incubation. The constraints of formal processes make design rationale easy to encode and enhance compliance, which in turn can aid subsequent decision making. Including explicit instruments to formally document creativity within design rationale may help designers to value it within their process.

Informal methods allow considerable freedom but also demand discipline if they are to be a useful compendium. Informal design rationale can be encoded freestyle and later transcribed, or it can be encoded in parallel, where programmers code decisions as they are made. Informal methods can be passive, such as videotaping, or active and explicit in capturing design processes and materials. In design studios, for example, informal compendiums of the design process can include recorded logbooks, Post-it wall and smart board images, concept maps, brainstorming sessions and conclusions, discussions and choices of methodologies, scenario design, and refinement or prototyping processes. In open source software and do-it-yourself communities, informal design rationale compendiums can include information transfer links (von Hippel, 2005), for example, logged communication channels and forums, e-mail, chat, and community websites such as www.linuxforums.org, instructables.com, [sparkfun](http://sparkfun.com), newgrounds.com, or e-how.

To fully understand design rationale's potential to support creativity, a system of evaluation is required. Amabile's (1983) consensual assessment technique can comparatively evaluate diverse implementations of design rationale. Take for example the assessment of design rationale across four conditions of a 2 x 2 experiment in which individuals or teams engage in a creative task with informal/formal x fine/coarse design rationale. Programmers who have been selected as judges based on their interrater reliability (the degree to which judges' ratings of creative products correlate with each of the others' ratings) can evaluate the creativity of the processes and products of these teams. The findings would inform the development of best practices for supporting creativity through design rationale.

Instantiation

Implementations of design rationale within a design process can occur at multiple levels. For example, design rationale practices can be structured to occur as a philosophy, protocol, schedule, tool, interface, or system. Different individuals and organizations will place different

values on design rationale as a philosophy, from considering it a core attribute to simply ignoring it. Similarly, compliance with the practice of design rationale may be enforced strictly, or followed only on an as-needed basis. With or without a philosophy, design rationale can be implemented as a protocol with guidelines and rules regarding its implementation. As a schedule (which may or may not be an element of a protocol), design rationale can be regulated, either on a time or event (i.e., new idea or change in course) basis. As a tool, interface, or system, design rationale can take a simple form or be mediated through multiple points of view (e.g., from the perspectives of various stakeholders). It can take place through e-mail, on-line activity, or even multiperson interfaces with virtual team members acting as design facilitators and design rationale elicitors. In the context of our considerations of design rationale as a creativity support tool, it is worth noting that creativity and support for creativity can also be considered at multiple levels (granularity, formality, instantiation, organizational, etc.).

Organizational

Regardless of the level of formality and granularity and its instantiation, the essence of the value of design rationale is that it provides a record of the reasons for a particular choice and preserves relevant consideration of alternatives, which in turn enables discussion, revision, reflection, and community building. Implementation of design rationale to facilitate creativity inherently takes place within the context of an organization and/or culture; that context has consequent impact on creativity and design rationale. Recent theory in creativity research has been generated both from large-scale cultural and organizational contexts and from individuals and small teams, while design rationale, at least at the point of its generation, has by and large focused on individuals and small teams. The environments' impact on design rationale can be considered in terms of its adoption and usage, and measured in terms of its benefits and efficacy in supporting creativity and the community. A full discussion of the relationship between design rationale and the context of its implementation is beyond the scope of this paper. Nonetheless, our exploration of creativity research and its appreciation for organizational influences on creativity can improve understanding of how design rationale can foster creativity.

In terms of organizational scale or complexity, applications of design rationale and creativity research can focus on relatively small organizations, ranging from individuals to small teams, and can extend to the broader issues of larger organizations, such as divisions, companies, and large-scale distributed communities, as are found in open source. Most environments in which design activity and creativity take place have their own forms of ad hoc design rationale that, at least in part, foster creativity. To the extent this is true, there exists the potential to apply lessons from both creativity research and design rationale to further enhance communication, creativity, and design outcomes. Design projects, ranging from architectural or landscape planning to writing a novel to software development, involve sketches (i.e., drafts, prototypes, or templates) that allow for the exchange and development of initial ideas and project requirements. When individuals and small teams work closely together, design requirements and possible solutions are frequently less complicated and more easily communicated across the team than when such projects are developed by larger organizations. Larger organizations must negotiate common agendas and effective strategies to build design rationale into their organizational structures and practices. Take, for example, individual software developers employing class and Unified Modeling Language diagrams to establish system architecture features and objectives as they manage initial

requirements. These sketches can be challenging, ambiguous, and cumbersome for small-scale organizations. However, in the context of a large-scale open source design community, project requirements and solutions are often difficult to articulate and agree upon. In order for these larger organizations to make progress, communication and the exchange of ideas and assumptions between peers is necessary. The communal development of this common understanding encoded by information transfer links (von Hippel, 2005) is a form of large-scale organizational design rationale, which, in turn, can support organizational progress and creativity.

Beyond the realm of software organizations, emergent hacker spaces and their commensurate on-line communities are an exciting contemporary open source phenomenon, the next generation of physical/digital design and human-computer interaction (Buxton, 2007). Increasingly, successful software is the product of integrated development, with well-defined software design attributes that are consonant with the hardware. For example, Apple's Multi-Touch trackpad technology, which allows users to navigate their electronics using various motions and gestures, makes use of both hardware and software affordances.¹ These synergies and designers' understandings between and across hardware and software systems are rapidly evolving within open source and do-it-yourself design communities. These communities develop not only highly creative hybrid physical/digital artifacts, but also expertise and social engagement among their members.

As described above, design rationale covers the spectrum from fine-grained descriptions of all reasoning processes to an organizational structure that provides guidelines to share creativity in the commons. In many contexts, the implementation of design rationale advances the principles and purposes of a creativity support tool.

CREATIVITY RESEARCH

Developing a design rationale that serves as a creativity support tool first requires an understanding of the field of creativity research. Creativity researchers suggest that the quality of creativity can be evaluated based on the value and level of meaning of a new idea product. In this vein, Csikszentmihalyi (1996) claimed that different people and groups experience creativity in multiple ways. Researchers also may distinguish ordinary creativity—small departures, insights, and innovations in everyday life—from the creativity of the few known geniuses, such as Einstein and Van Gogh. Gardner (1994) expressed the former as “little c” creativity as opposed to “big C” creativity. Within creativity research, creativity is recognized as a natural part of ordinary human existence. Shneiderman (2003) described these forms of creativity as everyday, evolutionary, and revolutionary. Since any advancement in society requires some new idea or process, creativity researchers also appreciate that creativity is an important process for societal transformation. Moreover, creativity is an integral cognitive process that is a fundamental part of human makeup.

In creativity research, creativity is considered to be present within any product or process that is novel and appropriate (Sternberg & Lubart, 2007), and is a part of everyday life and work activity (Certeau, 1984), in contrast to the more popular conception that creativity primarily occurs through “Eureka!” moments. French philosopher Michel de Certeau (1984) was one of the first theorists to propose the concept of everyday anonymous creativity by ordinary people. The many innovative ways that people recycle, adapt, or transform everyday

objects for their own benefit demonstrate everyday acts of creativity and design. This idea has taken hold in interaction and design research as well (Wakkary & Maestri, 2007). Photographer Richard Wentworth (1978), for example, created a photo series aimed at reframing our conception of everyday creative acts—using a bottle cap as a makeshift ashtray, or jamming an alarm clock with a half-eaten candy bar. Wakkary and Maestri (2007) reported similar everyday creative acts within families. Amabile (1983) developed the consensual assessment method as a way to rank creative acts. Studying activities such as writing poetry, building block towers, and making collages, she conceptualized a continuous creativity spectrum that ranks degrees of creativity. Her research demonstrated that judges, selected for their high degree of interrater reliability can be used to perform consensual evaluation of the creativity of most processes or products. In a range of studies, this method has been shown to have strong validity and is one of the most widely used and accepted evaluation methods in creativity research. The consensual assessment method could also be used to evaluate creativity in the process of design and compiling design rationale.

Amabile (1996; Amabile & Mueller, 2002) has studied the structure of creativity within individuals and developed the componential model of creativity that identifies three components within the individual that have an effect on creativity: an individual's intrinsic motivation; his/her thinking style; and his/her domain-relevant skills. Intrinsic motivation includes attitudes, perceptions of personal motivation toward a task. Domain-relevant skills include knowledge about the domain, technical skills, and talent. Thinking style includes convergent/divergent processes and implicit/explicit knowledge and appropriate use of heuristics for generating, evaluating, and implementing ideas.

In addition to the componential model's three elements within the individual, Amabile (1983) also identified environmental influences as a fourth component that affects team processes. Her studies of high-tech team collaborations "in the wild" have demonstrated important factors, including the role of affect; time pressure; focused attention; sequestered and prioritized creative activity; motivation; feedback; and actualizing rewards (Amabile, Hadley, & Kramer 2002; Amabile & Kramer, 2003). Actualizing resources and rewards are those that empower individuals to achievements they would otherwise not be capable of. For example, mentorship, tutorials, and on-line forums in open source software and do-it-yourself communities are actualizing resources for their members. Actualizing rewards might be an invitation or resources to attend a conference or lead a team that could assist in furthering already successful endeavors. In a series of studies creativity researchers have found that positive affect promotes creativity both in the moment and from one day to the next. Positive affect may come in the form of a small gift or joke, or as a positive event, breakthrough idea, or actualizing reward for progress in recognition of the creative activity. Open source communities often display elements of creativity support that are consistent with the framework developed by creativity researchers; existing frameworks for identifying and evaluating creativity can inform our discussion of creativity in these communities.

OPEN SOURCE COMMUNITIES

Open source software is characterized by its free availability to be modified and used by anyone, under a few sets of restrictions. The open source agreement restrictions generally

prohibit the use of code in commercial ventures. Open source on-line communities have their origins in the hacker culture, which is an example of what von Hippel (2005) called communities of “lead users.” Lead users’ adoption of toolkits and development of creative projects are core attributes of von Hippel’s notions of advancing democratic innovation. In the early 1990s, research laboratories, such as MIT’s Artificial Intelligence Laboratory, started licensing their software, restricting access to source code. Some lead programmers of the original source codes were upset by this control over what they felt was community property. In addition, several felt that this level of commercialization severely inhibited the growth of the field. This is an example of what Amabile & Mueller (2002) would call an environment that failed to provide “actualizing rewards.”

Stallman proposed the GNU General Public License (GPL) in the 1980s.² GPL grants the right to use software, to study and modify the source code, and to distribute or redistribute modified or unmodified versions at no cost. Furthermore, GPL restricts the right to use or incorporate the code into proprietary commercial software. In 1998, the open source software movement was formalized by Perens and Raymond. This movement emphasized benefits of sharing source code as we see today (DiBona, Ockman & Stone, 1999; Corbet, Kroah-Hartman, & McPherson, 2010; von Hippel, 2005). The open source movement resonated with individuals who were motivated to be part of the anticorporate culture that was emerging in response to big corporations such as Microsoft and their emphasis on closed system software. In contrast to the restrictive environment (described above), the environment created by GPL could be described as an actualizing one, in which the success of one’s creative products were shared and adopted widely and had visible impacts.

The scale of the open source community is significant. As of July 2011, more than 300,000 software projects have been registered on the Website sourceforge.net, a database of open-source software projects. The success of open source communities is largely explained by the intrinsic motivation of its contributors, who code and share information based on their intrinsic interests and domain expertise and act socially to engage in creative activity.

The rights granted by GPL have enabled the open source community to grow; this growth has required concerted conversation about the community’s agenda and decision making at the macro (within the structure of the community) and micro levels (within the code). This conversation and the deliberations now present a robust ad hoc design rationale corpus of the community’s endeavors. This corpus and the practices of the community around decision making and strategies for progress therefore form a basis for discussion of macrolevel design rationale.

CREATIVITY IN OPEN SOURCE COMMUNITIES

Open source communities are made up of programmers who are engaged in collaborative group activity, making the capture and effective communication of individuals’ design process and decision making particularly important. Open source communities use diverse modes of communication, forming unique structures that foster widespread everyday creativity. O’Mahony (Stark, 2003) investigated several characteristics of open source communities, finding that open source software developers are intrinsically motivated, value informality, and have distaste for “administrivia” (Stark, 2003). These characteristics are in line with a preference for informal and coarse-grained design rationale. However, as

O'Mahony (Stark, 2003) pointed out, some open source communities have formalized their organizational structures by creating formal boards and designated management roles. Design rationale can be seen to sustain the communal and creative goals of open source communities through a range of granularities, formalities, and organizational elements.

There are parallels between the existing functions of creativity support tools (see below) and the organization of open source communities. To more fully understand the interplay of creativity in open source communities, we now review the roles users play in the process of software coding in open source paradigms. A project is introduced by owners (also referred to as “maintainers” or even “gatekeepers”) who are responsible for project management. These project managers also set up an infrastructure for the project that those interested can use to seek help, provide information, or provide new open source code to test and discuss. People download the projects that attract interest and “play” with the code. Some of these people go on to create new and modified code. New code, deemed to be of interest and value by the project maintainers is authorized (von Krogh, Spaeth, & Lakhani, 2003), and posted back into the infrastructure. In essence this parallels the four-stage process of advancing creativity within information technology contexts, described by Shneiderman (2003) in his book *Leonardo's Laptop*, as a process comprising collecting (domain expertise, information collection), relating (analogical transfer, comparison among works), creating (development, testing), and donating (dissemination, diffusion). In open source communities, the credibility of members is determined through status, experience, and expertise. The roles can also overlap. Typically none of the roles are strictly enforced and most work is voluntary and intrinsically motivated, key parts of Amabile's (1983) componential model of creativity.

O'Mahony (Stark, 2003) identified three great challenges within the open source software paradigm that both inform our discussion and present opportunities for design rationale to support creativity. The first of these challenges is resources. The effective use of resources as actualizing rewards can be an opportunity for fostering a commitment to design rationale and as a tool for promoting intrinsic motivation and creativity. Second, the tension between creative freedom and need for structure and management is at the crux of the debate about the compatibility of design rationale and creativity (Carroll, 2010); the appropriate balance of formality and granularity can be difficult to find. Third, the need for sustaining pluralism in governance presents the classic challenge of individual and shared voices and shared language (O'Mahony & Ferraro, 2007). These are common challenges present in what Rittel (1972) termed “wicked problems.” Werner and Rittel's (1970/1979) participatory approach to the development of the issue-based information system (IBIS) and its use as a tool for design rationale have advanced approaches to shared dialogue; recent work on computational support and analysis of shared dialogue systems have further advanced these strategies (Conklin, 2003). Effective journalism (a record and forum for the communication and debate of multiple perspectives) can lead to effective policy and ultimately toward effective governance of a community, providing an actualizing environment within which to advance creativity. Beschastnikh, Kriplean, and McDonald's (2008) studies of organization and governance within Wikipedia support this; they characterized Wikipedia's “policy environment [as]—user editable, reflective of [best] practice, and easily citable” (p. 34). Further, they highlighted the potential for effective policy to foster public deliberation (Beschastnikh et al., 2008). At its core, this is what design rationale, and in turn advancing creativity (especially in open source communities), is about—creating an environment in which shared understanding, decision making, collaboration, and transdisciplinary creativity can occur.

Von Hippel (2005) argued that open source communities are innovation niches that foster widespread group creativity. He defined innovation communities as “nodes consisting of individuals or firms interconnected by information transfer links which may involve face-to-face, electronic, or other communication” (von Hippel, 2005, p. 96). These information transfer links are key features where understanding and fostering effective forms of design rationale can be most productive in enhancing creativity. According to von Hippel, innovation in these communities is a distributed process that occurs through both informal (user-to-user) and organized (users interacting within communities) cooperation. The community supplies users with useful tools and infrastructure that are employed to develop, test, and diffuse their innovations. In some important respects, von Hippel’s distinction between informal and organized information transfer links recalls the distinction, discussed earlier, of formal and informal approaches to design rationale. In the informal conditions of von Hippel’s arguments, and those advanced by this paper, the ad hoc nature is both useful, since it is spontaneous and responsive to opportunity (e.g., to discuss an important issue or capture, in the moment, salient design rationale), and problematic, since the lack of structure can lead to omission. In the organized or formal condition, the rigid context is productive, in that it allows for organizational progress and the capture of widely agreed upon relevant information; yet the formal condition also runs the risk of missing key information that falls outside of its categorization, such as divergent or minority viewpoints. Luther, Kelly, Ziegler, and Bruckman (2010) suggest that the success of creative collaboration in open source communities relies on leaders with solid reputations and respect from their communities, and that Weber’s (2004) principle, “Talk a lot,” should be encouraged.

Within open source communities, diverse levels of domain expertise and transdisciplinary collaboration are leveraged to foster what creativity research would describe as fluency and flexibility. Because these “low-cost innovation niches” (von Hippel, 2005, p. 79) consist of novel combinations of and within preexisting elements and contexts (the members and organizations that exist within the community and the ongoing development of the source code), members typically draw on their own expertise to advance creative solutions. For example, in the realm of open source and do-it-yourself communities, an individual with a background in mountain biking (a hobby) and orthopedic surgery (a profession) may create a seat suspension that reduces shock to a biker’s spine upon landing. Thus, collectively, the community’s members are capable of generating a wide range of ideas (fluency) owing to their diverse backgrounds and a broad diversity in the type of ideas (flexibility). Open source communities, therefore, attract people from various backgrounds who are motivated by the same ideals to create or develop upon existing platforms, whether these are source code or electro-mechanical systems, knitting communities, or so on. The different combinations of backgrounds of the participants in the open source communities and their interconnections are aimed at enhancing the potential quality of the final products. This presents opportunities and challenges for design rationale to act as a cross-pollinator, to bridge the expertise and domain gaps, and to foster transdisciplinary communication.

In open source software development, where the transdisciplinary nature of the community is somewhat less diverse than in the open source or do-it-yourself communities, participants still take on a range of roles that allow them to apply their expertise to a wide range of shared interests and problems that serve the communal goals. To support the sharing of their expertise and advancement of their projects, these communities typically utilize

various forms of version-control tools that facilitate beta testing and revising processes. In open source software developer communities, the volume of individuals who can test and debug code increases the chances that a bug will be found; as Raymond put it, in a phrase that has come to be known as the Linus Law, “given enough eyeballs, the bugs are shallow” (2001, p. 30). The current paradigms for idea exchange in open source software developer communities are through forums or e-mail lists, forms of asynchronous informal communication that aim to focus on single issues in each thread. The main limitations to the effectiveness of current forms of ad hoc open source design rationale within these communities are the duplication and repetition of ideas. For a new developer, therefore, the onus lies in searching and rediscovering whether or not a certain idea or problem has occurred before and what the possible resolution of that idea might have been. New forms of design rationale or strategies for motivating more constructive implementations of design rationale in open source communities may be able to mitigate these limitations. For example, the Wikipedia community uses “barnstars” to reward their members’ effective contributions to articles and commentary (Beschastnikh, McDonald, Zachry, Kriplean, & Borning, 2009). One way to interpret the success of the debugging process in open source communities is that users’ diverse roles, backgrounds, and expertise allow them to view and discuss issues from multiple perspectives. Collective perspectives and implicit analogies enable them to overcome errors and recover from failure.

It is significant to note that design rational systems should include not only the rejected alternatives, but also, and more importantly, the failed implementations that constitute the valuable experiences needed to form the basis of analogies from which further work, progress, and breakthroughs can be advanced. As Dunbar’s (1994) creativity research studies of expert and nonexpert scientific teams show, individuals and teams with more domain-relevant knowledge to draw on can more readily draw parallels between failures and new, more productive domains through analogical reasoning, thus empowering them to overcome setbacks and realize solutions more effectively. In open source communities, users who come from a range of disciplinary backgrounds can use analogies implicitly, both for recognition of bugs as well as for creation of new applications. Advanced design rationale systems have the potential to go beyond their current roles to encourage users to record not just successes and rejected alternatives, but also experiences and reflections of failures as well. This type of design rationale might serve as supporting scaffolding for the development of appropriate analogies and access to generative tools (Gero, 1996; Ishikawa & Terano, 1996). For example, people who download programs could submit a failed version explaining what problems they encountered, how they tried to solve it, if they failed, and why. This record of failures would allow others developers to either not go the same route or take this up as a challenge and introduce improvements and insightful alternatives.

Individuals engaging in transdisciplinary knowledge sharing in open source communities can discover options that were originally neglected. Members play varying roles in groups that may be different from their own personal background and in turn can influence open source successes in creation and rediscovery. The challenge in realizing improved creativity is perhaps in the realization of these benefits; here, design rationale has a significant role to play. Design rationale can empower members of the group to take on, evaluate, and rationalize decisions from new, diverse, and informed perspectives that challenge and provide the community with paths to move their common agenda forward. One of the biggest challenges is the sharing of

unique information that each member possesses in the context of pooling common resources to balance the roles of team decision making. This balance serves both as a means to engender acceptance of, satisfaction with, and commitment to decisions, and to combine disparate points of view, knowledge, and ideas towards better decisions. In contrast to many other group settings, the opportunity to share and capitalize on the benefits of unique information increases with an increase in the number of members in open source communities.

The discussion of creativity and von Hippel's (2005) thesis on democratic innovation within open source communities echoes several of the models of creative processes proposed in decision sciences and creativity literature. For example, according to Cashman and Stroll (1989, p. 136), information technology-based decision processes can be expressed as a "create, communicate, review, and react" action cycle (including awareness management, autonomy, information gathering and dissemination, structuring, modeling options, and execution). Similarly, Shneiderman's (2003) collect, relate, create, and donate stages of creative processes within IT environments and von Hippel's (2005) analysis of open source communities, provide us with insights into the creative processes inherent to these open source communities. As such, these environments provide fertile ground to advance the interplay between creativity research and new forms of design rationale that are fundamentally creativity research tools.

CREATIVITY SUPPORT TOOLS

In order to advance an understanding of the potential of design rationale to act fundamentally as a creativity support tool for open source communities, it is necessary to review recent developments in the realm of creativity research tools. Over the past decade or so, the goals of fostering creativity at the individual and group levels within the context of computing have evolved, furthering the domain of creativity research tools. The Association for Computing Machinery's Conference on Human Factors in Computing Creativity and Interface Workshop in 2002 focused on opportunities to use interface tools in fostering end-user creativity. Common themes of the discussion included interface elements that offered "exploration, parallel experimentation, generative ideation, media and content pliability, iteration, support for creative mistakes and insights and process assistance" (Burlison & Selker, 2002, p. 89). A subsequent National Science Foundation (NSF) Workshop on creativity research tools (Shneiderman et al., 2006) highlighted the potential of creativity research tools as offering "more effective searching of intellectual resources, improved collaboration among teams, and more rapid discovery processes, ... potent support in hypothesis formation, speedier evaluation of alternatives, improved understanding through visualization, and better dissemination of results, ... [to] facilitate exploration of alternatives, prevent unproductive choices, and enable easy backtracking" (p. 62). A set of guidelines for creativity research tools were developed, encouraging a "low threshold, high ceilings, and wide walls" (Shneiderman et al., 2006, p. 70); in other words, easy entry to usage for novices, powerful facilities for sophisticated users, and a small, well-chosen set of features that support a wide range of possibilities, easy exploration of multiple alternatives and powerful history-keeping.

Creativity research tools can take many different forms to support these objectives, encompassing a variety of activities. Shneiderman (2003) demonstrated this in the context of

multiple professional domains and organizations, including architects, lawyers, doctors, and the Compumentor and TechSoup communities. NSF's Creative IT (NSF, 2009), a 3-year funding initiative and the community it fostered, further advanced creativity research tools to explore their role in assessing creativity in everyday activities. Following up on Amabile and Kramer's (2003) study of the creative practices of high tech researchers, creativity investigations have advanced multimodal real-time tools that computationally track affect, voice, and motion "in the wild" and relate these to self- and peer-report measures (Burleson & Pentland, 2008). Similar tools have been advanced to detect diverse affective states, including frustration at 79% accuracy (Kapoor, Burleson, & Picard, 2007). States of frustration and failure in turn present opportunities to promote affective self-awareness and/or algorithmic thinking that have been shown to be instrumental in fostering creative solutions to challenging problems and setbacks (Dunbar, 1994).

Just as open source community programmers and do-it-yourself hackers can be encouraged to use design rationale tools to communicate their reasoning process to others who build upon their code and artifacts, design rationale can also act as a creativity support tool to foster reflection. Empowering users at appropriate times, such as times of frustration and failure, to learn from analogies (Dunbar, 1994) can be conducted by encouraging them to describe their design rationale choices, both for decisions and practices that were eventually implemented and those more exploratory approaches that were not. Further coupling these with the underlying reasoning as to why they were chosen will allow for design rationale tools to provide the creativity support tool features of a low threshold entry for beginners and a high ceiling for experts to encourage a broader engagement by the community. Although this may sound onerous and fine-grained, we are seeing some initial elements of these types of explanations and design rationale emerging within open source communities, such as Linux developers and the do-it-yourself instructables.com hacker postings and their responsive feedback and discussion groups.

Open source and do-it-yourself communities foster broad participation, expertise development, and communication for novice and experts alike. Within the instructables.com community, we see exciting examples of information transfer links that serve as ad hoc design rationale. Take, for example, robonerd's³ "Do It Yourself Arduino or 'The DIY-Duino'" (robonerd, 2010) that describes how to make a version of a popular microcontroller from scratch. In response to a community member's interest in minimizing the board size, robonerd augmented the original tutorial's description to provide additional ad hoc design rationale, explaining his appreciation of the anthropomorphic qualities of the spatial layout of the circuit, "... when you look at it vertically, it kinda looks like a face.... I just couldn't change the look on that face!" (March 7, 2011). There is also evidence that the Linus Law (Raymond, 2001) helped robonerd with debugging, "I see it, SHOOT! I thought you were talking about the elec caps not the ceramics. Crud, I gotta fix that! Thank you very much for the catch! I appreciate it" (March 7, 2011). The multiple perspectives of the community also offer suggestions for new directions. David97 said, "I want to remote control my arduino using my xbox controler (bluetooth). how can I do this?" (March 7, 2011). Motivation for expression of rich design rationale can be sustained through positive feedback and extended mentorship: jpr3 said, "This was a GREAT tutorial. Your web site had each and every step documented! Great work!!!!!" (March 9, 2011). Through a detailed dialogue involving 10 posts, robonerd mentored angelovalorreed until his/her microcontroller worked; robonerd

then agreed to update the instructable to include further detailed suggestions: “I’m going to keep the iable as it is though, because if you use the exact components listed, it works like a charm. Though I will add a suggestion to try the caps you used when in use with that crystal” (March 16, 2011). Throughout this and other such communities, elements of design rationale are affected by the organizational structures (tutorials and comments) and by governance policies, which support a range of formality and granularity. There are typically higher levels of formality and granularity in the tutorials than in the comments. Instructables’ policy that allows individuals to remove posts (erniehatt said, “I removed the comments because I found a couple of errors”; March 17, 2011) allows community members to alter the history of the design rationale. On the one hand, this allows users to correct errors; on the other hand, it may ultimately inhibit the community from learning from failures. Within these forums, design rationale is not always supportive of creativity; as noted above, there are redundancies, nonsequiturs, and even occasional detractors.

Providing design rationale guidelines that encourage developers to encode design rationale for not only the choices they pursue but also for nonelected choices is likely to encourage others to explore a wide range of alternatives (e.g., through analogy), ultimately leading to more successful and creative processes. Such a process of open source community development and appreciation for broader forms of design rationale is likely in turn to foster the wide walls that are necessary for creative exploration. Studying how design rationale can not only foster its own recording and reviewing processes but also how these can be better understood as synergistic with, and indeed as key elements of, creativity support tools within open source communities will help to advance better choices for the implementation of new design rationale strategies. It also will foster stronger understandings of best practices for encoding and disseminating expert (and nonexpert) deliberation and insight, from which a broader community can learn, and support the development and advancement of their creative endeavors. This can be achieved through the development of a deeper understanding of both the processes and consequences (beneficial and detrimental) of design rationale implementation informed by the perspective of creativity research.

The Creativity and Cognition (C&C) conference⁴ community focuses on the nexus of creativity, cognition, design, and emerging technologies. As open source and do-it-yourself communities have emerged, C&C’s interests have included understanding design processes and design rationale related to hybrid physical/digital tools for fabrication and collaboration. A study of the design of “egg drop challenge” devices⁵ showed that providing designers with tools and resources that foster fluency (lots of ideas) and flexibility (a range of diverse ideas) affected their design rationale practices. Individuals who were provided fewer eggs engaged in fewer opportunities to test their designs. Their explanations of their designs and process (their design rationale) revealed that they were less fluent and flexible in their design process and reflection than were their counterparts who were given many eggs (Dow, Heddleston, & Klemmer, 2009). Likewise, their products were less effective and less creative. An explicit example of this can be seen where the mental frame in which designers approach problems, and hence expressed design rationale, is affected by the environment, tools, and resources, in ways that impact elements of their creative process and outcome. This demonstrates that broad access to actualizing resources can directly impact design rationale and the creativity of processes and products (Amabile & Kramer, 2003; Dow et al., 2009). Related work shows that prototyping in parallel is more creative than prototyping sequentially (Dow et al., 2010). Open source software development

environments and gaming worlds also address issues of fluency, flexibility, and prototyping by offering sandbox opportunities that act as “playgrounds” and rapid prototyping environments with which to explore and develop ideas and relationships. Examples of this in the realm of educational gaming include Shute and Becker’s (2010) advancement of 21st century assessment that places an emphasis on the importance of learning to think creatively through data mining of learners’ activities and collaborations in educational gaming environments. Furthering this agenda, Wegerif et al. (2010) have demonstrated the ability to automatically recognize creative reasoning in student e-discussions within in situ dialogue analysis of intelligent tutoring learning environments and their data streams. These examples present opportunities that can inform the development of design rationale implementations as creativity support tools.

COMPUTATIONAL CREATIVITY, EXPERTISE, AND TEAMS

Now that creativity support tools and their potential in design rationale for open source communities have been presented, we explore more recent findings in the area of team and computational creativity research that offer opportunities for future work and development. These should serve as related resources that offer opportunities for the community that is advancing design rationale as creativity support tools.

Team Brainstorming

Smith (2003) proposed that in order to achieve a new way of thinking in a team, members must ignore an existing “fixated” point of view (i.e., sticking with one perspective or idea to the detriment of the overall process) and arrive at a nondominant point of view. The dominant response tends to block minority responses. This characteristic is evident within team interactions when a big idea starts gaining more weight in spite of its possibility of failure or incompatibility with team objectives. This often occurs due to the familiarity (or safety) of the idea, tendencies of teams to want to agree (groupthink), or individuals’ production blocking. Therefore, maintaining and advancing divergent points of view during a large group discussion can be a difficult and daunting task.

In shared brainstorming activities, a high number of ideas often are generated, with one of them subsequently being selected based on discussion of merit with respect to context. A key role of team decision making is to engender acceptance, satisfaction, or commitment to decisions. Smith (2003) suggested that groups should go further, striving to play an important role in combining disparate points of view, knowledge, and ideas towards better decisions. As will be discussed below, open source software communities contend with the interplay of these two roles as they engage in building and generating acceptance for various versions of the open source software code.

One proposed solution is to maintain a log of ideas, avoiding discussion until every idea has been enumerated, such as in electronic brainstorming via individual contributions (Sutton & Hargadon, 1996). However, the simple log that this form of brainstorming creates still requires revisiting each idea, thinking it through at both the individual and group levels, and then deciding on the merits of all of this with respect to the group agenda. This latter process

typically still requires group-level communication, which again is often confounded by fixation and the effects of interpersonal hierarchy.

Recent work on feedback in group settings has shown that higher individual and/or group self-awareness leads to self-directed adaptation of behavior (DiMicco & Bender, 2007). DiMicco and Bender showed that public visualization of group members' verbalization leads to subsequent moderation or improvement of participation, resulting in stronger group outcomes. For example, participants who talk too much will tend to talk less when a bar graph publicly portrays them as an outlier; group members who do not talk enough likewise tend to talk more. For low participating members, talking more fulfills their normative needs, but more importantly provides them with sufficient conversational bandwidth to contribute beneficial information that would otherwise not be available to the group. Such strategies of group self-awareness may also allow higher attention to group processes, goals, and strategies (West, 1996). Gersick and Hackman (1990) found that work groups can break dysfunctional habitual routines by self-reflection. Farooq, Carroll, and Ganoë (2007) found that group self-monitoring can enhance the understanding of breakdowns of creativity and lead to prevention of breakdowns.

Understanding team creativity research with respect to the nature of the work a group shares can provide insights into the functioning of open source communities. Tjosvold (1998) showed that creating a common task that requires collective action among members of a team can induce cooperative orientation, thereby promoting resource and information exchanges as well as openness to each other's ideas. Similarly, Wageman (1995) found that teams employing task interdependence increased the need for collaboration and mutual adjustment among members by raising the collective sense of responsibility among team members. Thus, we may conclude that the overall success of team creativity can be ensured by creating conditions of common fate with rewards and/or task interdependence. While the specifics are not well understood, interesting insights about the importance of leadership and active participation are emerging (Luther et al., 2010). These conditions of common fate along with cooperative orientation help to drive today's open source culture.

Thus, a significant opportunity for creativity support in open source communities is to sufficiently reduce sources of inhibition such that each member may engage in adequate expression of ideas. Through the customization and promotion of environments that encourage design rationale expressed through information transfer links, users can be encouraged to share their unique contributions. Tools that support various means to enhance the discussion of individuals' ideas without exacerbating team members' inhibitions are likely to lead to increased team creativity.

Influence of Expertise and Computational Systems

Building on the context of creativity support in teams, we will now discuss expertise with respect to team and computational creativity. In addition, we address how improved understandings of dynamics within their processes might inform implementation of design rationale as a creativity support tool in groups.

Atman et al.'s (2007) research on individual problem solving demonstrated that experts engage in iterative processes—ranging across information gathering, problem definition, modeling, evaluation, reflection, and so forth—that are richer than those of their novice counterparts. Experts engage in activities that allow them to accumulate experience, reflect on

them, and transfer their experience and knowledge between diverse stages and activities within design processes; they also engage in significantly more reflection than novices. Here we see that level of expertise impacts both design rationale practices within design process and the outcomes of these open-ended creative activities. Similarly, organizational approaches to design (e.g., organizational processes that pursue iterative design vs. sequential design, sometimes referred to as the waterfall model) impact design rationale and creative outcomes. We have conducted pilot studies applying Atman and colleagues' approach to groups engaged in design processes, exploring the question: If a weaker designer joins a team, does the team become weaker or does the weaker designer rise to the occasion and improve his/her performance (Burleson, 2007)? Due to the complexities of conducting team studies, this remains an open question. We also currently are exploring the potential for an embodied agent to participate as a virtual facilitator to prompt shifts in individual or team activities.

Similar processes and questions arise in the realm of efforts to advance computational creativity and its interactions with individuals and integration with teams, for instance in systems aimed at demonstrating expertise and fostering effective team collaboration and creativity. Buchanan (2001) approached computational creativity in terms of metacreativity. He argued, as summarized in Burleson (2005, p. 443), that programs should "provide the ability for the AI [artificial intelligence] to accumulate past experiences and information, reflect on them, and transfer this information throughout the system, as a means for enhancing creative collaboration between machine and user." Even in computational systems that do not yet operate with Buchanan's (2001) metacapacity, there is strong evidence for the potential of creative systems to play a significant role within hybrid teams. Goldenberg, Mazursky, and Solomon's (1999). "Creative Sparks" research, published in *Science*, demonstrated that a computerized routine (one easily algorithmically implemented by humans) "produces solutions consensually judged to be more creative than those achieved by humans" (Burleson, 2005, p. 443). Yet when this algorithm was made available to human teams, they failed to recognize or realize its benefits, opting instead to pursue their task without the aid of the computational creativity system. This example shows that even when computational creativity is highly capable, there is still significant work to be done on the social elements of human-computer interaction to encourage its acceptance by a human team. This example also shows that the team was not sufficiently appreciative of the algorithm as one of its actualizing resources to advance creativity. The creativity process and its outcome could be improved by a design rationale implementation that had sufficient formality and granularity to encourage effectively and persuade the team to record and reflect on the creative resources and concepts at its disposal, and with decision-making support that helped individuals and teams select the most creative ideas (regardless of their origin).

Ultimately, given the advances in computational creativity, humans and computers could work on hybrid teams to foster creativity. Facilitating a frame of collaboration between the creativity support tool and humans is one of the ongoing opportunities for design rationale and creativity support tools, and advances the Computing Research Association's (2002) Grand Challenges. The range of attributes that we find in creativity support tool approaches, if applied to design rationale at the individual and group levels, would arguably have the potential to enable design rationale to serve as a creativity support tool to foster higher levels of creativity, in both processes and outcomes. Since many of the approaches discussed above lay the foundation for enhancing creativity through design rationale at the individual and team levels, they also

hold important strategies for implementation of design rationale that supports creativity and acts as creativity support tool within open source communities. Specifically, the creativity support tool guidelines (low thresholds, wide walls, powerful history-keeping, etc.) could be applied throughout open source community information transfer links, within the user or system interface, as a community-level guideline, and as a design rationale philosophy promoted by the community. Merging Shneiderman's (2003) collect, relate, create, and donate approach to systems that foster creativity with Amabile et al.'s (2002) and Amabile & Kramer's (2003) findings from organizational behavior studies—specifically by sensing elements of organizational behavior and understanding positive affect and frustration, time pressure and interruption—could guide, tailor, and refine open source communities' implementation of design rationale as creativity support tool. Open source and do-it-yourself communities that employ actualizing resources and rewards consistent with lessons from creativity research and from individual and team expertise can more effectively use design rationale to enhance the fluency and flexibility elements of creativity. Design rationale can play an important role in understanding better ways to incorporate technological support (computational creativity and creativity support tools) in hybrid teams.

CONCLUSION

Applying findings from creativity research and recent efforts that have advanced creativity support tools has the strong potential to realize significant advances to design rationale, both in terms of evaluating diverse implementations of design rationale for their ability to foster creativity and toward transforming existing design rationale tools into creativity support tools. These lessons can and should be used to guide efforts to transform existing design rationale tools into design rationale–creativity support tools. In this manner, a range of organizational practices and innovative interfaces that include appropriate levels of granularity and formality can foster creativity through novel design rationale implementations and enhancements. These might include features that encourage metacreativity and promote users' ability to engage in the expert practices and rich processes that emphasize reflection, transfer, learning, and recovering from failure through analogy. They might also identify times of failure and frustration, and might create sandboxes or equivalent features that foster fluency and flexibility, providing low thresholds, wide walls, and actualizing rewards for creativity. They might minimize time pressure and promote opportunities for positive affect and productive social interaction. While these strategies can be employed throughout programming, design practice, and indeed in any context in which design rationale may apply, they are particularly relevant to open source software and do-it-yourself communities that are highly active in advancing new forms of creative collaborations and creative IT endeavors.

ENDNOTES

1. Multitouch is a technology that allows Apple products to recognize when two or more points are in contact with its surface, enabling two-finger scrolling, rotation, zoom, etc.
2. The Free Software Foundation is a nonprofit that campaigns for free open source software and drives development of the GNU license. For more information, go to <http://www.fsf.org>

3. The quotes excerpted from the Do It Yourself Arduino (The DIY-Duino) have been quoted exactly as written. These forum comments took place during March 2010, and the dates of specific comments are included within parentheses.
4. Creativity & Cognition is an annual conference run by the Association of Computing Machinery, which brings together professionals from diverse fields to discuss the depth and breadth of human creativity.
5. The Egg Drop challenge is a popular engineering challenge in which participants are given a limited set of materials (often straws, paper, or toothpicks), and asked to create a device that will allow an egg to be dropped from a specified height without breaking.

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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 creativity 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

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, 2005), 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, Duguid, & Haviland, 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, Giaccardi, Eden, Sugimoto, & Ye, 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, Lemke, McCall, & Morch, 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.

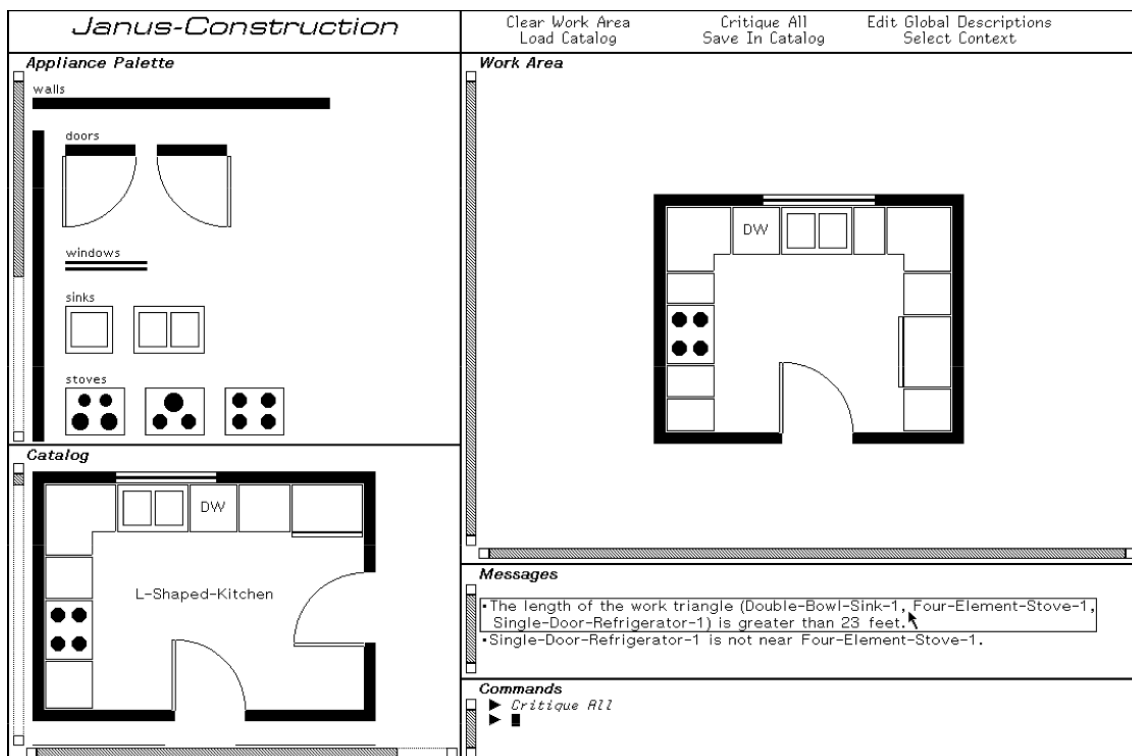


Figure 1. JANUS-Construction: A DODE for kitchen design.

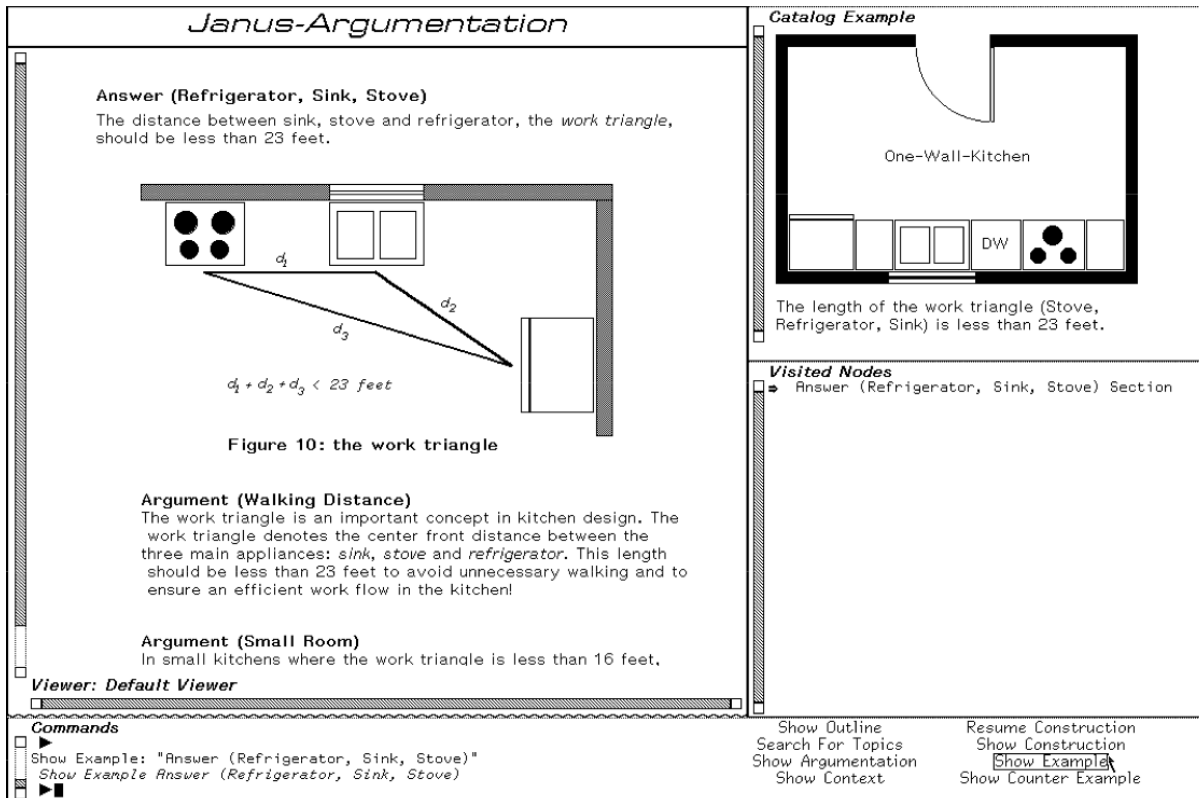


Figure 2. JANUS-Argumentation: A DODE for kitchen design.

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, Nakakoji, Ostwald, Stahl, & Sumner, 1998);
- 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;
- 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 within universities, schools, offices, and communities advocates 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 also 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, Levine, & Teasley, 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, Fischer, & Ostwald, 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—



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

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, Ko, & Burnett, 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;

- 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, Nakakoji, Yamamoto, & Kishida, 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.

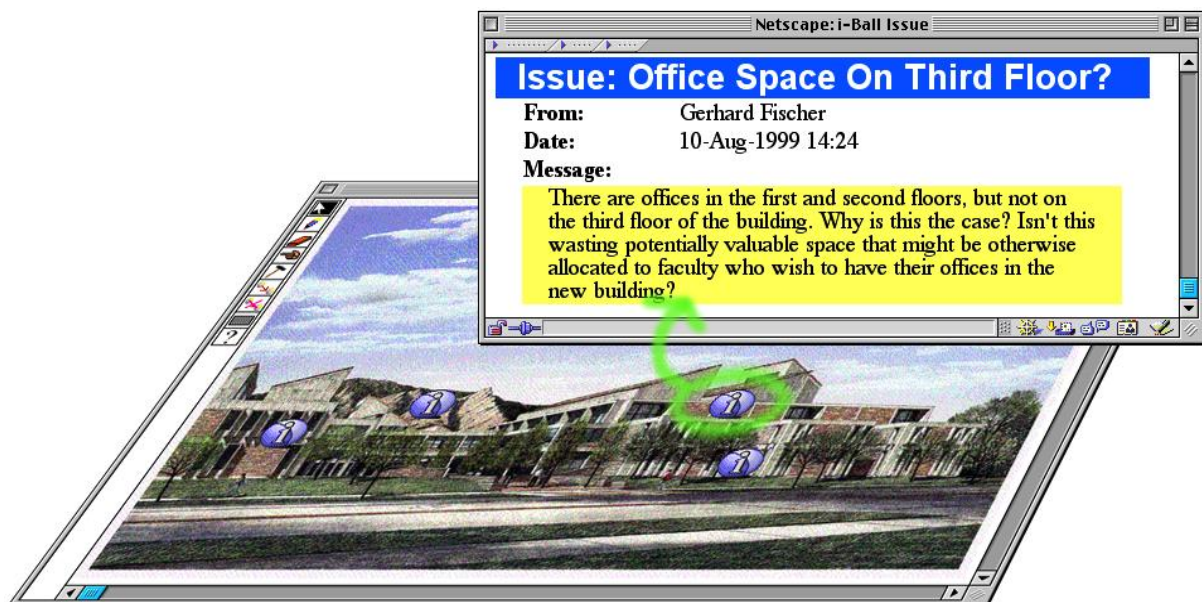


Figure 4. The association of design rationale with buildings in the EDC.

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.

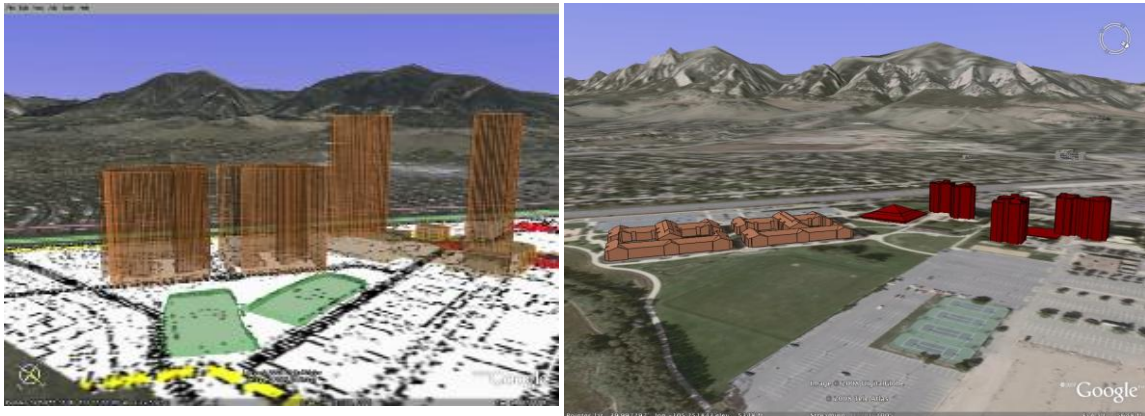


Figure 5. Visualization and incremental formalization in EDC.

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 graphical user interface 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:

- There are clear individual preferences for modes of expression when designing interfaces. Some stakeholders will work around the limitations of the system, for

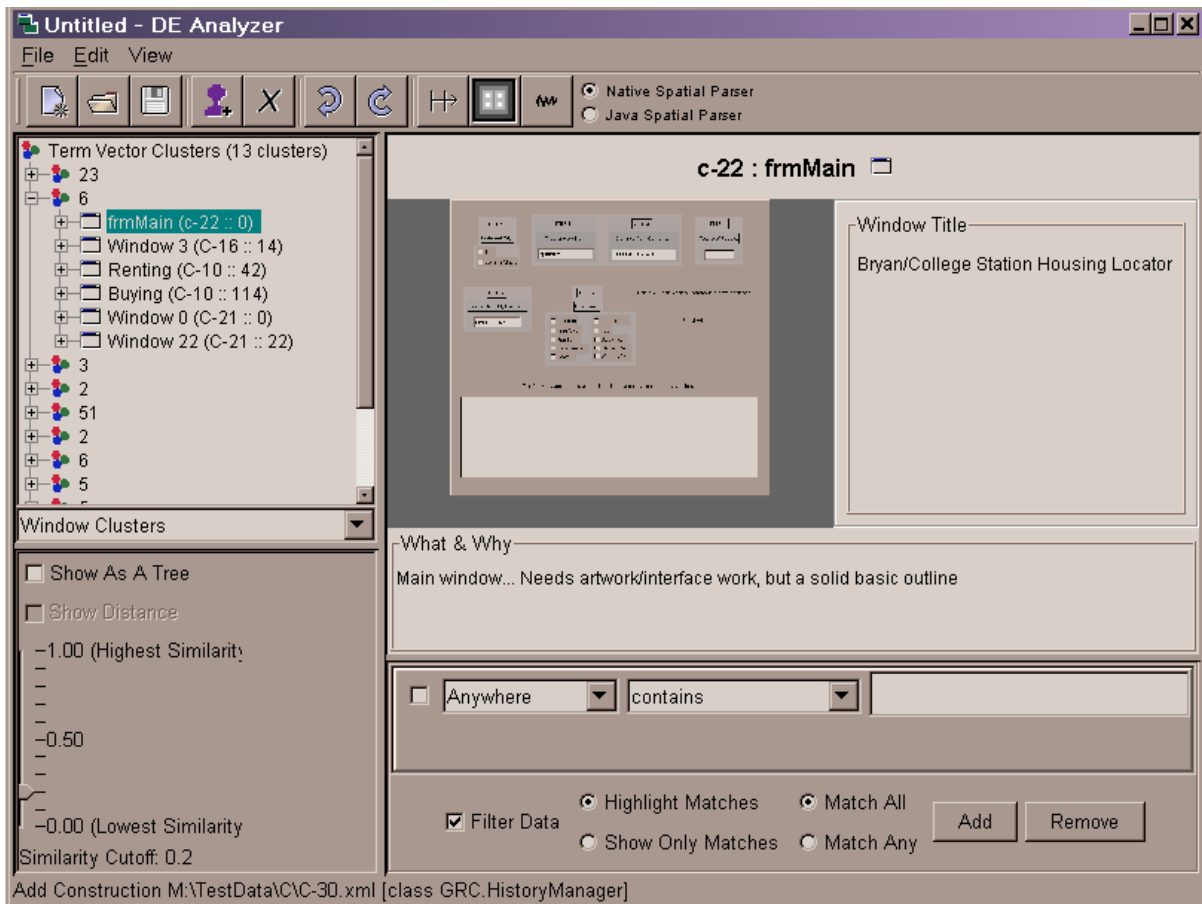


Figure 6. DE Analyzer showing reduced view of design and associated text.

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.

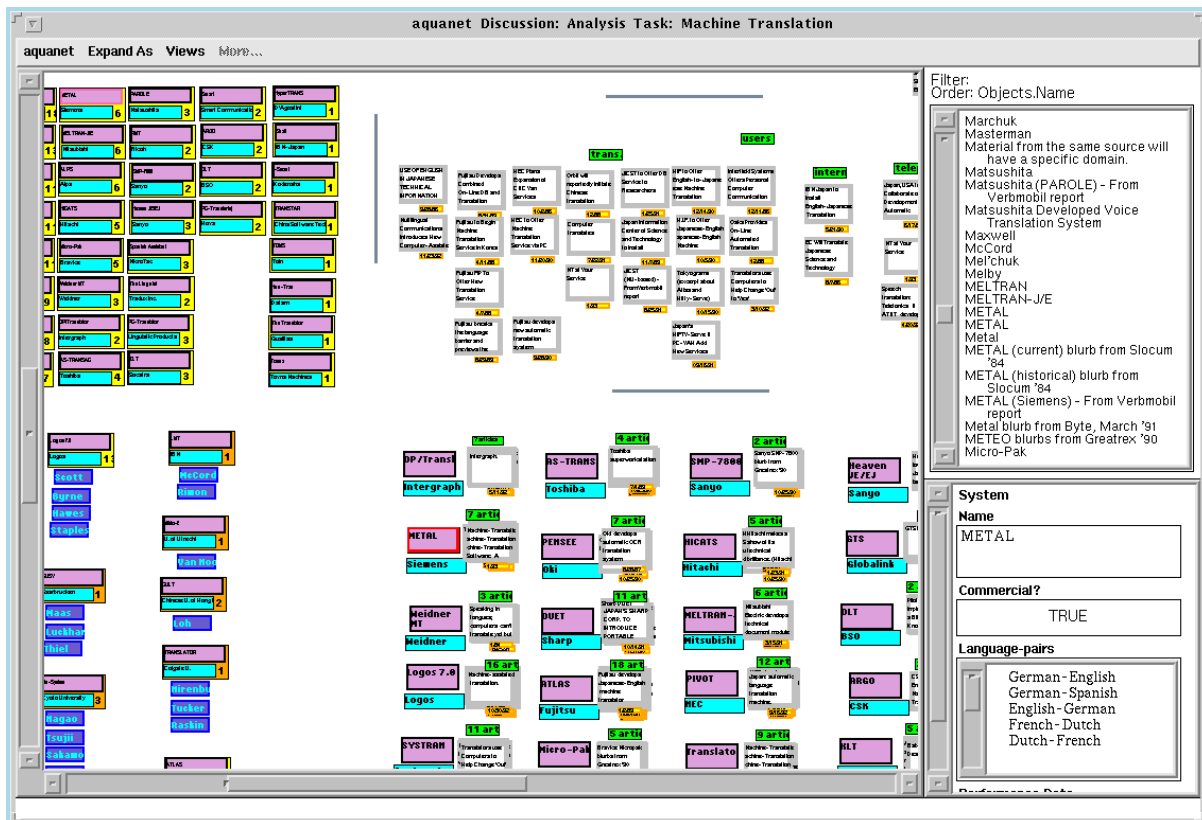


Figure 7. Visual structures expressing semantic relations between people, companies, publications, and software systems in Aquanet.

Aquanet, developed by Catherine Marshall and colleagues at Xerox PARC (Marshall, Halasz, Rogers, & Janssen, 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

these layouts (Shipman, Marshall, & Moran, 1995). In VIKI (Marshall, Shipman, & Coombs, 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, Moore, Maloor, Hsieh, & Akkapeddi, 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

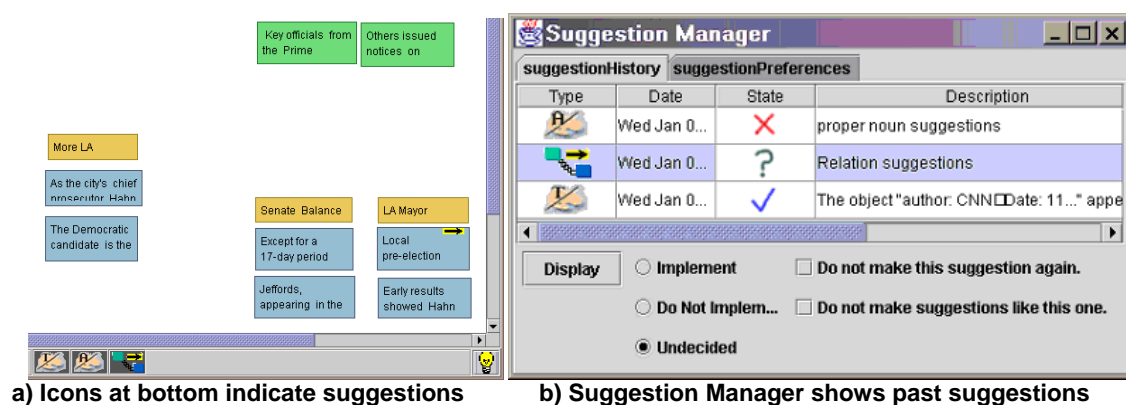


Figure 8. Suggestions in VKB aim to decrease effort required to capture semantics. The left figure shows icons indicating new suggestions while the right side shows suggestion details.

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 with 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.

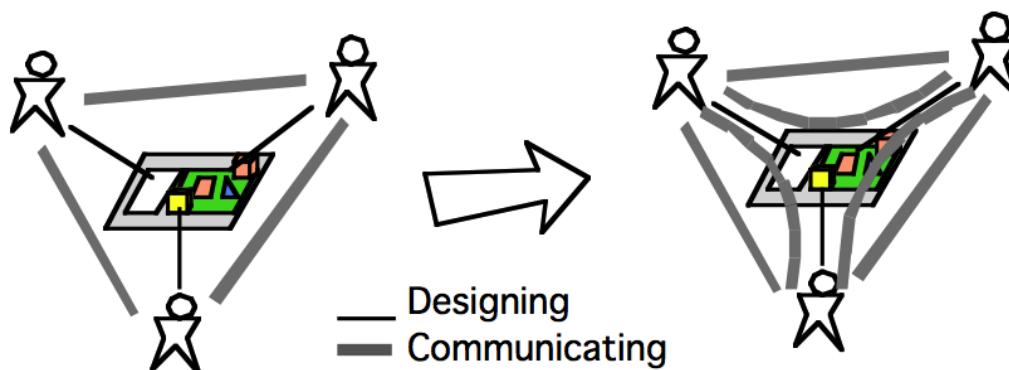


Figure 9. “Storing the Artifact” versus “Mediating Design and Communication” architectures.

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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