Symmetry of Ignorance, Social Creativity, and Meta-Design

Gerhard Fischer

Center for LifeLong Learning & Design (L^3D)
Department of Computer Science and Institute of Cognitive Science
University of Colorado, Boulder
gerhard@cs.colorado.edu

Abstract

Complex design problems require more knowledge than any one single person can possess, and the knowledge relevant to a problem is often distributed and controversial. Rather than being a limiting factor, "symmetry of ignorance" can provide the foundation for social creativity. Bringing different points of view together and trying to create a shared understanding among all stakeholders can lead to new insights, new ideas, and new artifacts. Social creativity can be supported by new media that allow owners of problems to contribute to framing and solving these problems. These new media need to be designed from a meta-design perspective by creating environments in which stakeholders can act as designers and be more than consumers.

Keywords

conceptual frameworks for creativity and cognition, consumers, designers, impact of new media on design, meta-design, social creativity, symmetry of ignorance

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INTRODUCTION

Creativity is often associated with art; our research work in the Center for LifeLong Learning & Design (http://www.cs.colorado.edu/~l3d/), however, is concerned with the creativity that is required in everyday work practice by emphasizing the importance of lifelong learning during these activities. The analysis of everyday design practices has shown that knowledge workers and designers have to engage in creative activities to cope with the unforeseen complexities of everyday, real-world tasks. This type of creativity is in most cases not *historical*—that is, the activity or the product is not necessarily novel or original to a community of practice or society as a whole—but *psychological*, meaning it is personally novel and meaningful to the stakeholders who produced it [Boden, 1991]. Although analyzing outstanding creative people contributes toward establishing a framework for creativity [Gardner, 1993], understanding creativity in the context of everyday activities is equally important for letting people become more productive and create better work products. This paper explores three interrelated concepts: symmetry of ignorance, social creativity, and meta-design. These concepts are illustrated with examples developed in our research over the last ten years.

Symmetry of Ignorance

"The clashing point of two subjects, two disciplines, two cultures ought to produce creative chaos." — C.P. Snow

Design. Design problems are ill-defined and complex and must be treated as a "universe of one" [Schön, 1983]. Although designers often make use of specific, well-established knowledge from mathematics, science, and engineering, they also create new knowledge in the course of understanding the unique aspects of their problems. In this regard, design problem solving is an interdisciplinary activity, bringing together multiple perspectives from different areas of expertise.

The predominant activity in designing complex systems is that participants teach and instruct each other [Greenbaum & Kyng, 1991]. Because complex problems require more knowledge than any single person possesses, communication and collaboration among all the involved stakeholders are necessary; for example, domain experts understand the practice, and system designers know the technology. Communication breakdowns are often experienced because stakeholders belonging to different cultures [Snow, 1993] use different norms, symbols, and representations. Rather than viewing this *symmetry of ignorance* [Rittel, 1984] (or "asymmetry of knowledge") as an obstacle during design, we view it as an opportunity for creativity. The different viewpoints help in discovering alternatives and can help uncover tacit aspects of problems.

When a domain reaches a point at which the knowledge for skillful professional practice cannot be acquired in a decade, specialization will increase, collaboration will become a necessity, and practitioners will make increasing use of reference aids, such as printed and computational media supporting external cognition. Design [Simon, 1996] is one such domain *par excellence.* Complexity in design arises from the need to synthesize different perspectives of a problem, the management of large amounts of information relevant to a design task, and understanding the design decisions that have determined the long-term evolution of a designed artifact. Design problems are wicked and ill-defined; they are moving targets that often do not have solutions but only have resolutions [Arias, 1995], and the context in which these problems exist is by nature characterized by change, conflict, and multiple stakeholders. In many cases, the best we can strive for is not consensus, but informed compromises emerging from the conflicting arguments and goals among stakeholders.

To exploit the symmetry of ignorance requires putting owners of problems in charge [Fischer, 1994b], which will promote direct and meaningful interaction involving people in decisions that affect them. In order to bring important perspectives to the process of design, all stakeholders in the process should be designers and co-developers, not just consumers [Fischer, 1998a]. End-users, as owners of problems, bring special perspectives to collaborative design activities that are of special importance for the framing of problems. The "symmetry of ignorance" requires creating spaces and places that serve as *boundary objects* where different cultures can meet. Boundary objects serve as externalizations that capture distinct domains of human knowledge, and they have the potential to lead to an increase in socially shared cognition and practice [Resnick et al., 1991].

The following two sections apply the concept of symmetry of ignorance to two specific and quite different domains: as it occurs in the context of high-functionality applications, and as it provides an alternative view to the classroom view of learning.

EXAMPLE$_1$: SYMMETRY OF IGNORANCE AND HIGH-FUNCTIONALITY APPLICATIONS

High-functionality applications (HFA) [Fischer, 2000], such as Unix, MS-Office, Photoshop, Eudora, etc., are used to model parts of existing worlds and to create new worlds. They are complex systems because they serve the needs of large and diverse user populations. If we ask 100 different people what features they would like to have in a particular application, we will end up with a very large number of features. The design of HFAs must address three problems: (1) the unused functionality must not get in the way; (2) unknown existing functionality must be accessible or delivered at times when it is needed; and (3) commonly used functionality should be not too difficult to be learned, used, and remembered. We have conducted a variety of empirical studies to determine the usage patterns of HFAs, their structure, and their associated help and learning mechanisms.

Expertise in HFA. "Experts" (users who know everything about a system) no longer exist for HFAs. In such rich settings, being an "expert" is at best an attribute of a specific context, rather than a personal attribute. The different spaces of expertise (determined by individual interest) are illustrated in Figure 1. In this *multi-kernel model*, $\{D_1, U_i\}$ means the area of functionality D_1 that is well known to a particular user U_i; for example: U_1 knows about the equation editor, U_2 knows about mail-merge functionality, U_3 uses a bibliography system for references, and U_4 is familiar with collaborative writing tools (D_4 represents the functionality of the system as a whole). The diagram graphically illustrates the "symmetry of ignorance" among the users U_1 - U_4.

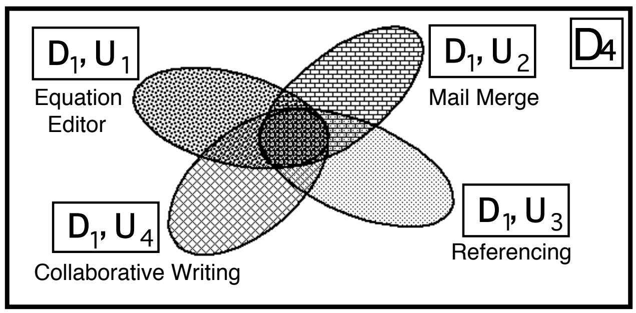

Figure 1: Distributed Expertise in HFAs

EXAMPLE$_2$: SYMMETRY OF IGNORANCE: A NEW VIEW OF LEARNING AND COLLABORATIVE KNOWLEDGE CONSTRUCTION

Accepting that most design problems are characterized by a "symmetry of ignorance" leads to a different view of learning. In these contexts, relevant knowledge, which needs to be drawn out of and synthesized from the perspectives of the contributors, does not exist *a priori* and cannot simply be passed on by those who have it to those who need it. Therefore, approaches are required that view learning as collaborative knowledge construction [Scardamalia & Bereiter, 1994]. This view is in sharp contrast to the teaching cultures of our schools [Illich, 1971], by which teaching is often "fitted into a mold in which a single, presumably omniscient teacher explicitly tells or shows presumably unknowing learners something they presumably know nothing about" [Bruner, 1996]. A critical challenge is to reformulate and reconceptualize this impoverished and misleading conception. Such a teaching culture may be realistic for the early grades in schools [Hirsch, 1996], but it is obviously inadequate for learning processes for which knowledge is distributed among many stakeholders and "the answer" does not exist or is not known. Historically, the roles of teacher and learner were associated with a person; in settings characterized by the symmetry of ignorance, however, being a teacher or being a learner is associated only with a specific context. "Official" teachers should feel comfortable becoming learners in many situations.

Most learning that takes place outside of a traditional (instructionist) classroom can be characterized as follows: humans are engaged in some activity (some action such as working, collaboratively solving a problem, or playing), they experience a breakdown (i.e., a piece of lacking knowledge, a misunderstanding about the consequences of some of their assumptions, etc.), and they reflect about the breakdown. Schön [Schön, 1983] calls this reflection-in-action. Because self-reflection is difficult, a human coach, a design critic, or a teacher can help the learner to identify the breakdown situation and to provide task-relevant information for reflection. In our own work, we have explored the possibility of using computational critics [Fischer et al., 1998b] to provide some of this support when humans are not present. Critics make argumentation serve design; this is, they support learners in their own activities.

Engagement and support for self-directed learning is critical when learning becomes an integral part of life—driven by our desire and need to understand something, or to get something done instead of solving a problem given in a classroom setting. Self-directed learning de-emphasizes teaching as a process in which a teacher tells something to a passive learner. In Figure 2, students may actively engage in teacher-provided homework, but they are passive because their control over the course of study is limited.

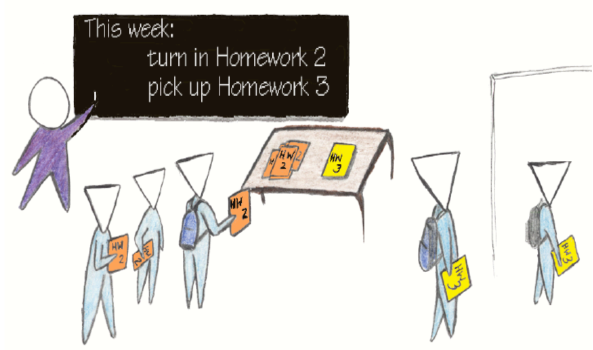

Figure 2: Passive Learning

In many situations, it is advantageous to give students the opportunity to direct their own learning to encourage motivation and the opportunity to acquire new knowledge [Fischer, 1991]. Therefore, teaching should instead focus on mutual dialogs and joint knowledge construction that is enhanced by the creation, discussion, and evolution of artifacts. In Figure 3, the teacher's role shifts from being the conduit through which information is transmitted into being a coordinator, facilitator, and coach.

Figure 3: Self-Directed Learning

A symmetry of ignorance perspective on learning and collaborative knowledge construction takes this a step further. Figure 4 characterizes learning situations in which no participant takes the role of a teacher. It provides a model for learning in a knowledge society that is built upon distributed cognition, articulate learners, peer-to-peer learning, and incremental enhancement of information spaces by a community of practice. Mutual competency supported by objects-to-think-with (externalization of ideas, concepts, and goals), leads to settings and opportunities for learning by all participants. Communication breakdowns are experienced because the stakeholders belong to different work cultures, which use different norms, symbols, and representations. Rather than seeing the symmetry of ignorance as an obstacle during design, it should be seen as an opportunity for creativity. Having different viewpoints helps stakeholders discover alternatives and uncover tacit aspects of the problems with which they have to cope.

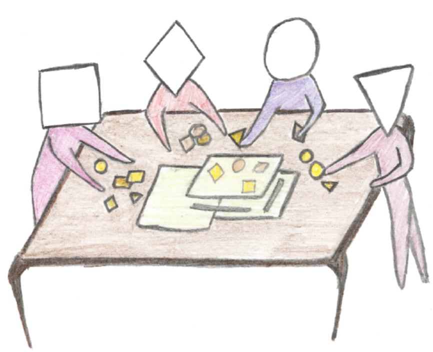

Figure 4: Symmetry of Ignorance — Learning by Creating Shared Understanding

Social Creativity

The power of the unaided, individual mind is highly overrated—"the Renaissance scholar does not exist anymore." Much of our intelligence and creativity results from exploiting the symmetry of ignorance as a source of power. Although creative individuals are often thought of as working in isolation, the role of interaction and collaboration with other individuals is critical [Engelbart, 1995]. Creative activity grows out of the relationship between an individual and the world of his or her work, and out of the ties between an individual and other human beings.

INDIVIDUAL CREATIVITY

Empowering individuals requires conceptual frameworks and computational environments that will give domain designers more independence from computer specialists. Past L^3D research has developed conceptual frameworks to empower individuals by developing *domain-oriented design environments* (DODEs) [Fischer, 1994a], which make the computer invisible, and bringing tasks to the forefront in a variety of different domains. By being domain-oriented, they support (1) breakdowns, (2) critics, and (3) learning on demand.

Breakdowns. A system supporting creativity will be sufficiently open-ended and complex that users will encounter *breakdowns* [Fischer, 1994c; Popper, 1965]. The system must provide means for allowing users to understand, extricate themselves, and learn from breakdowns. Rather than attempting to eliminate trouble, the system should help users manage troubles and exploit breakdowns as opportunities rather than failures. As any professional designer knows, breakdowns—although at times costly and painful—offer unique opportunities for reflection and learning [Petroski, 1985]. Breakdowns can occur at many levels—for example, at the tool level (e.g., computational environments do not provide the functionality needed), and at the domain level (e.g., domain designers are lacking or overlooking some important domain knowledge). To exploit these opportunities, we have developed conceptual frameworks and innovative systems to support critiquing and learning on demand.

Critics. *Critiquing systems* [Fischer et al., 1998b] offer advice and information by supporting reflection-in-action [Schön, 1983], thereby allowing users to explore the contextualized argumentation and design rationale associated with their actions. By using design environments, designers create artifacts that serve as externalizations of their thoughts [Bruner, 1996]. These artifacts can be critiqued by computational critics, increasing the "back-talk" of the design situation [Schön, 1983].

Learning on Demand. *Learning on demand* [Fischer, 1991] allows designers to explore contextualized information that is directly relevant to their breakdown situations. New learning environments are needed to circumvent the difficult problems of *coverage* (i.e., trying to teach people everything that they may need to know in the future) and *obsolescence* (i.e., trying to predict what specific knowledge someone will need in the future). Learning on demand is the only viable strategy in a world where we cannot learn everything. It is a promising approach to supporting creativity for the following reasons: (1) it contextualizes learning by allowing it to be integrated into work rather than relegating it to a separate phase; (2) it lets learners see for themselves the usefulness of new knowledge for actual problem situations, thereby increasing the motivation for learning new skills and information; and (3) it makes new information relevant to the task at hand, thereby leading to better decision making, better products, and better performance.

LACK OF SUPPORT FOR COLLABORATIVE DESIGN

In designing artifacts, designers rely on the expertise of others [Galegher et al., 1990] by referring to textbooks, standards, legal constraints, and especially previous design efforts. Complex design projects force large and heterogeneous groups to work together on projects over long periods of time. Information repositories that support such projects should include not only knowledge about the design process but also knowledge about artifacts of that process—parts used in designing artifacts, subassemblies previously created by other design efforts, and rationale for previous design decisions [Fischer, 1994a]. Designers generally have a limited awareness and understanding of how the work of other designers within the project—or in similar projects—is relevant to their own part of the design task. The large and growing discrepancy between the amount of such relevant knowledge and the amount any one designer can possibly remember imposes a limit on progress in design. Overcoming this limit is a central challenge for developers of systems that support collaborative creativity.

Distributed cognition [Norman, 1993] emphasizes that the heart of intelligent human performance is not the individual human mind but (1) groups of minds in interaction with each other or (2) minds in interactions with tools and artifacts. It is important to understand the fundamental difference between these two aspects of distributed cognition. When at work between the individual human mind and artifacts (such as memory systems), distributed cognition often functions well because the knowledge an individual needs is distributed between that individual's head and the world (for example: an address book, a folder system of e-mail messages, a file system). But in the case of interaction among a group of minds, the problem arises that *a group has no head*—therefore externalizations [Bruner, 1996] are critically more important for social creativity. Externalizations (1) create a record of our mental efforts, one that is "outside us" rather than vaguely in memory; and (2) represent situations that can talk back to us and form the basis for critique and negotiation.

KNOWLEDGE CREATION, INTEGRATION AND DISSEMINATION

To make social creativity a reality, we need new forms of knowledge creation, integration, and dissemination based on the observation that the scarce commodity in the information age is not information but human resources to attend to this information [Simon, 1996].

Knowledge Externalization. One aspect of supporting organizations and groups in creating knowledge is the externalization of an individual's *tacit* knowledge [Polanyi, 1966]. This is important for three reasons: (1) externalization causes us to begin to move from vague mental conceptualizations of an idea to a more concrete representation; (2) externalization provides a means for others to interact with, react to, negotiate around, and build upon the articulated knowledge; and (3) externalization provides an opportunity to create a common language of understanding. The use of external representations [Bruner, 1996] serves to focus discussions upon relevant aspects of the framing and understanding of the problem being studied and allows stakeholders to engage in a "conversation with the materials" of the design problem [Schön, 1983]. The ability to interact with the problem at hand and to have that situation "talk back" is a crucial mode of design. A principal challenge for social creativity is to capture a significant portion of the knowledge generated by work done within a community. Experiences with organizational memories and collaborative work have exposed two barriers to capturing information: (1) individuals must perceive a direct benefit in contributing to organizational memory that is large enough to outweigh the effort [Grudin, 1994]; and (2) the effort required to contribute to organizational memory must be minimal so it will not interfere with performing the work at hand [Carroll & Rosson, 1987].

Knowledge Integration. The challenge in social creativity is to integrate the various perspectives emerging from the symmetry of ignorance among articulate stakeholders. By supporting the process of reflection within a shared context defined by the task at hand, opportunities can emerge from enhancing the creation of shared understanding. This process melds the information that is collaboratively constructed into the problem-solving context, informing the process as well as the stakeholders and allowing them to participate from a more enriched and meaningful perspective [Brown et al., 1994]. It also enhances the quality of the designed artifact due to the synergy of interaction that draws out ideas and perspectives in a conversational manner. The resulting, richly contextualized information is available for future stakeholders to draw upon, informing them not only about the surface level of the design but also about the deeper characteristics behind the design. Collaborative constructions result in work products that are enriched by the multiple perspectives of the participants. The information repositories and organizational memories that are created in these ways are no longer very large, impenetrable "write-only" stores, but are actively integrated into the work processes and social practices of the community that constructs them.

Knowledge Dissemination. Humans seldom (if at all) explore large reflection spaces (e.g., thousands of pages of documentation, design rationales, argumentation, etc.) in the abstract [Moran & Carroll, 1996], but do so to obtain information in response to breakdowns [Fischer, 1994c] occurring in their design activities. Making information relevant to the task at hand (rather than drowning users in decontextualized information) and supporting the interaction of multiple perspectives and the various strengths that each stakeholder brings to the task allow collaborative exploration of the knowledge and shared understanding of the problem. The knowledge is made to serve the process of collaborative design by providing "the 'right' information at the 'right' time and in the 'right' way" [Fischer et al., 1998a].

EXAMPLE$_3$: DYNAMIC INFORMATION SPACES SUPPORTING SOCIAL CREATIVITY

There is a growing interest in dynamic information spaces. From the early conceptions of hypertext [Bush, 1945] to the current excitement regarding the World Wide Web and open source developments [O'Reilly, 1999], the potential to capture and manipulate dynamic information spaces has existed.

DynaSites [Ostwald, 2000] is an environment for creating and evolving collections of Web-based information spaces that are open-ended and grow through the contributions of users thereby supporting social creativity. Within L^{3}D, we have used DynaSites to develop a shared, evolvable glossary of concepts. The basic idea is that concepts are not fixed entities, put involve over time, especially in work groups characterized by a symmetry of ignorance among the participating stakeholders. Figure 5 illustrate this for the concept of "breakdowns" (readers are encouraged to explore the glossary system at: http://Seed.cs.colorado.edu/dynagloss.MakeGlossaryPage.fcgi).

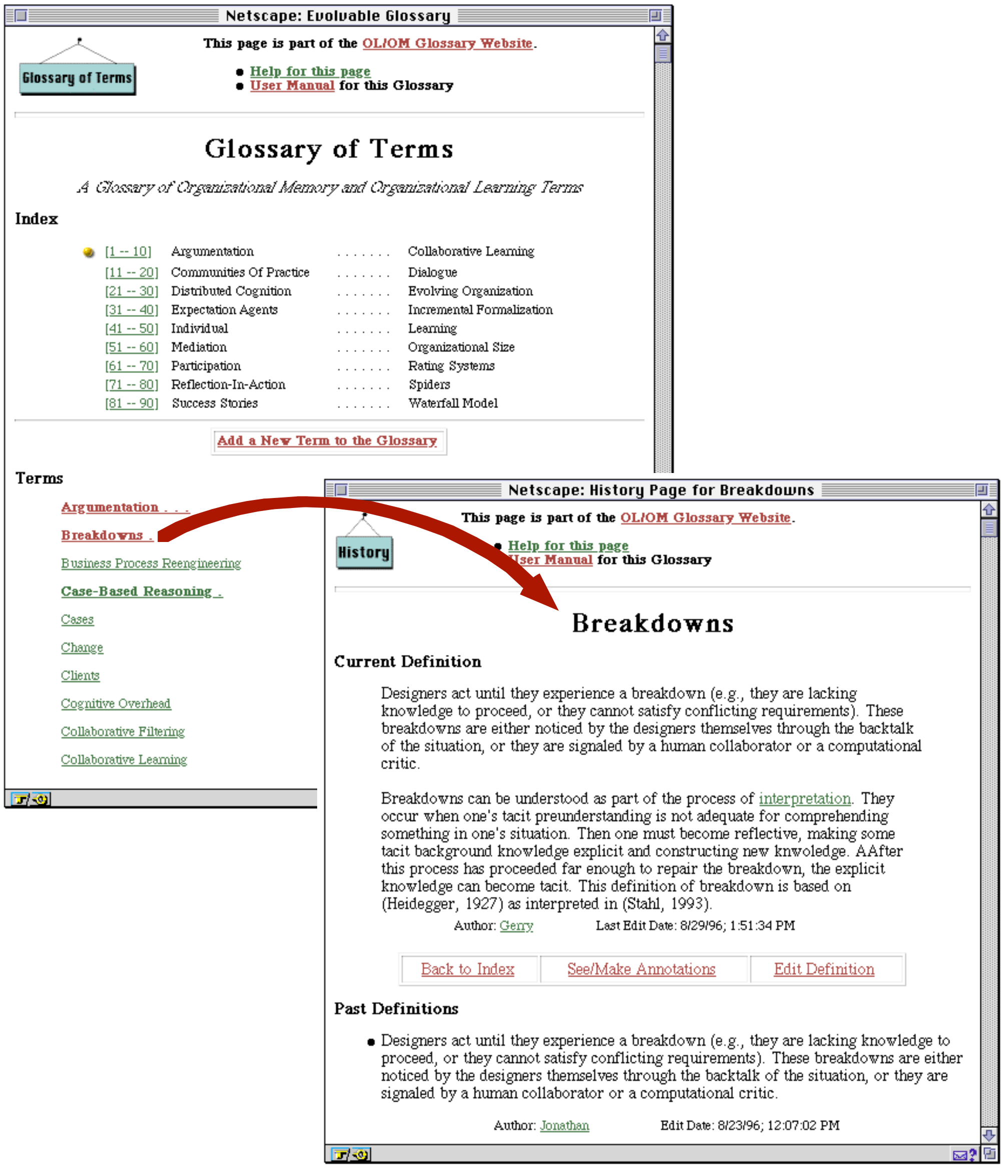

Figure 5: DynaGloss—a DynaSite Environment Supporting Collaboratively Evolved Concept Spaces

Another application of DynaSite in support of social creativity is a Virtual Library system developed in collaboration with a high school for collecting and sharing links to World Wide Web sites. Figure 6 illustrates the library in action, which is built on top of the DynaSites substrate. The Virtual Library provides *Workspaces* for making notes and collecting and annotating stack items that can be grouped into *Reserves*. An instructor, for example, might create a reserve for an American Literature assignment containing sites about famous American authors (the DynaSites Virtual Library can be found at: http://robin.bvsd.k12.co.us/virtlib/).

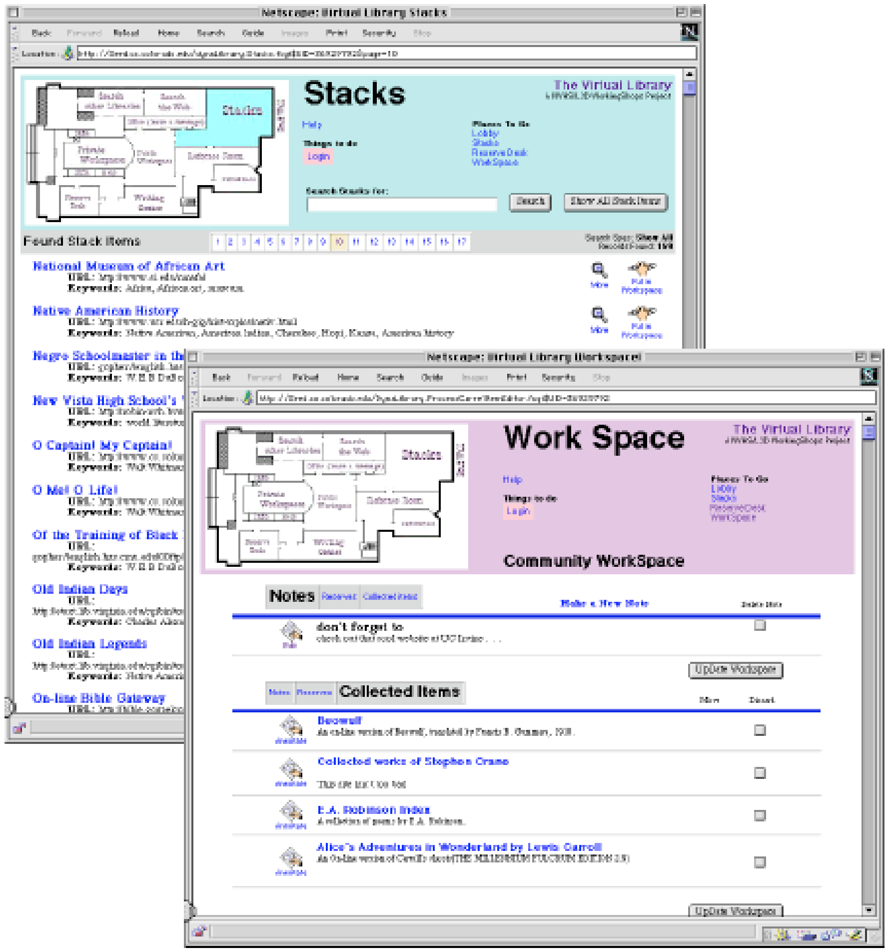

Figure 6: The DynaSites Virtual Library

META-DESIGN

A Chinese proverb says: "If you give a person a fish, you provide food for a day—if you teach someone to fish, they will have food for a lifetime." This saying can be extended by arguing that "if we can provide someone with the knowledge, the skill, and the tools for making a fishing rod, we can feed the whole community." *Meta-design* characterizes activities, processes, and objectives to create new media and environments that allow users to act as designers and be creative. This can be compared with the objective in art that focuses on the artist as the facilitator of the creative experience for users. In our work, we have explored a set of concepts and ideas for meta-design that are summarized in Figure 7.

Concept	Implications
convivial tools	allow users to invest the world with their meaning and to use tools for the accomplishment of a purpose they have chosen [Illich, 1973]
domain-orientation	bring task to the forefront; provide time on task [Fischer, 1994a]
critiquing	increase the back-talk of the artifacts [Fischer et al., 1998b]
open, evolvable systems	put owners of problems in charge [Fischer & Scharff, 1998]
underdesigned systems	create seeds and constructs for design support at use time [Fischer, 1998b]

Figure 7: Concepts of Meta-Design

One of the fundamental problems of system design is to write software for millions of users (at design time; see Figure 8), while making it work as if it were designed for each individual user (who is known only at use time). The need to support a broad class of different users leads to high-functionality applications with all their associated possibilities and problems. A feasible design strategy to support users in their *own domain of knowledge* is that system designers make assumptions about classes of users and sets of tasks in which they want to engage—a design methodology leading to domain-oriented systems [Fischer, 1994a].

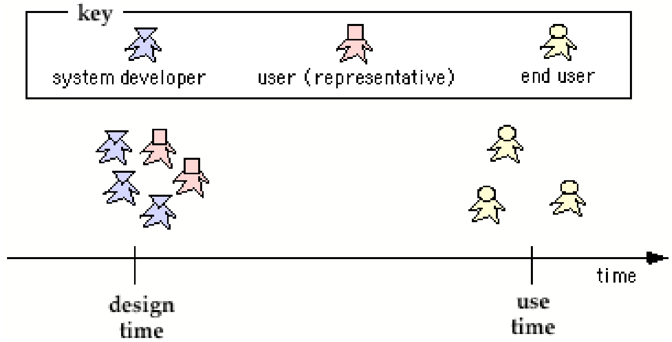

Figure 8: Design and Use Time

An important objective of meta-design is that design spaces is created at design time provide users at use time with interesting and varied design possibilities. If the system is constantly adapting or is being adapted to users, use time becomes a different kind of design time [Henderson & Kyng, 1991]. The need for meta-design is founded on the observation that design problems in the real world require *open systems* that users can modify and evolve. Because problems cannot be completely anticipated at *design time* (when the system is developed), users at *use time* will discover mismatches between their problems and the support that a system provides. A necessary, but not sufficient condition for meta-design is that software systems must have features that permit users to create customizations and extensions [Fischer, 2000].

EXAMPLE$_4$: THE ENVISIONMENT AND DISCOVERY COLLABORATORY

The Envisionment and Discovery Collaboratory (EDC) [Arias et al., 2000] is a meta-design effort that acknowledges the "symmetry of ignorance" as a fundamental design constraint. It supports social creativity by empowering stakeholders to act as designers—allowing them to create shared understanding, to contextualize information to the task at hand, and to create objects-to-think-with in collaborative design activities. The EDC framework (http://www.cs.colorado.edu/~l3d/systems/EDC/) is applicable to different domains, but our initial effort has focused on the domains of urban planning and decision making, specifically in transportation planning and community development.

The EDC is a meta-design approach with the goal of creating environments that are *immersive* and *emergent.* An *immersive* environment allows stakeholders to become deeply engaged in problem solving in the context of information, action, reflection, and collaborations relevant to the situation, whereas an *emergent* environment addresses the need for this context to grow and evolve based on ongoing problem-solving activities. These intertwined concepts require the EDC to support stakeholders in (1) creating and capturing knowledge in the context of collaborative design activities; (2) sustaining the timeliness and utility of evolving information; (3) articulating their own knowledge in a form that other people can understand; (4) enhancing existing knowledge with new knowledge; and (5) creating tools that help stakeholders think, and help analyze their constructions and artifacts.

Figure 9 shows the current realization of the EDC environment supporting "around-the-table" interaction and contextualizing information in design activities. Individuals using the EDC convene around a computationally enhanced table, shown in the center of the figure. This table serves as the *action space* for the EDC. Currently realized as a touch-sensitive surface, the action space allows users to manipulate the computational simulation projected on the surface by interacting with the physical objects placed on the table. The table is flanked by a second computer that drives the vertical touch-sensitive computational whiteboard serving as the EDC's *reflection space*. In the figure, users are using the reflection space to fill out a Web-based transportation survey that provides in part the information base associated with the model being constructed in the action space. The reflection and action spaces are connected by communication between the two computers using the Web as a medium. The entire physical space, through the immersion of people *within* the representations of the problem-solving task, creates a prototype of an integrated, socio-technical human-computer system. The open nature of the EDC supports integration of new constructions and differing perspectives into the environment. The dissemination of constructed knowledge is afforded through the EDC's WWW linkages between the action and reflection spaces. These constructions can be shared in a distributed manner just as distributed information can be integrated through the reflection space.

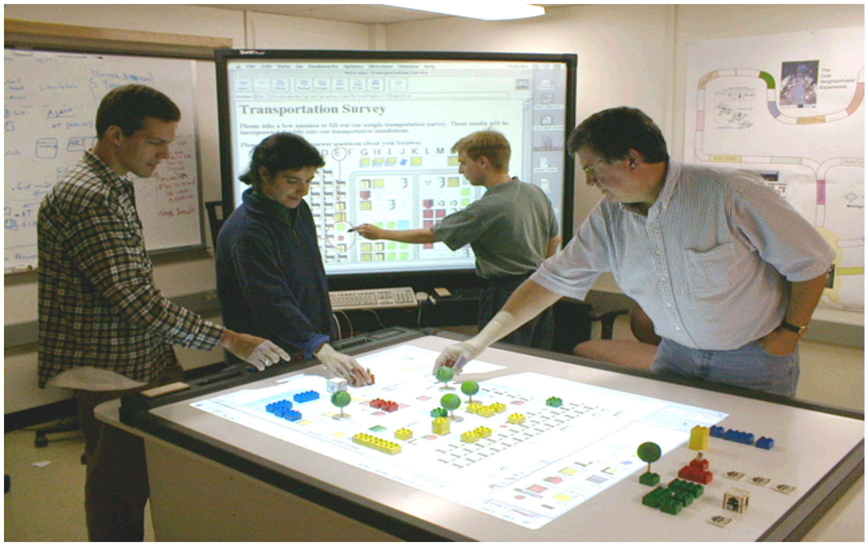

Figure 9: The Current Prototype of the EDC

The EDC represents a theory-based architecture and process model with three layers: (1) a *domain-independent framework and architecture* for integrated physical and computational environments that support creating shared understanding through collaborative design; (2) *application domains,* in which the domain-independent architecture is realized for a specific class of problems (for example, the application domain discussed in Arias et al [Arias et al., 2000] addresses decision problems of urban planning, specifically for transportation systems); and (3) *specific applications* created to contextualize an application domain to a concrete situation, such as transportation planning in the city of Boulder.

The "symmetry of ignorance" among the stakeholders in the EDC serves as a source for social creativity by providing users with many opportunities to construct their own situations and have control in the description of a problem. For example: neighbors can change the model and see how their changes affect the transportation system. They can place new buses along a bus route to increase bus frequency along the route; or they can move bus stops, change the bus route by moving appropriate pieces, and modify the behavior of the buses or traffic lights. In the course of framing and solving their problems, neighbors may find that the existing environment does not model some situations in which they are interested. The meta-design allows *stakeholders* to extend the system to meet the needs of unforeseen situations.

Computational Substrates Embedded in the EDC. To exploit the symmetry of ignorance and to support social creativity, the EDC incorporates a variety of computational mechanisms and substrates. The action space of the EDC is built using AgentSheets [Repenning, 2000], a software environment for creating simulations and domain-oriented environments. AgentSheets applications include a collection of autonomous computational processes, called agents, that are comprised of a look (their on-screen representation), and a programmed behavior. Agents in AgentSheets are programmed in *Visual AgenTalk*, a programming environment suitable for end-user programmers.

The reflection space in EDC is supported by *DynaSites* [Ostwald, 2000], which allows users to create extensible, Web-based information spaces (see Example$_3$). DynaSites provides computational support for collaborative working, learning, and knowledge construction by supporting these activities in a way that they can grow and be shaped over time by the people who use them. DynaSites information spaces are dynamic because their pages are built at *use time* (from a database) whereas typical Web sites are static—their links and displays are determined at *design time*. They differ from most Web sites because they are dynamic and evolvable by users.

ASSESSMENT

The environments presented in this paper represent explicit attempts to instantiate and evaluate the adequacy and usefulness of a framework grounded in the concepts of symmetry of ignorance, social creativity, and meta-design. We live in a world where problems often require the collaboration of stakeholders from different communities, seeing the world from their individual perspectives, having their own background knowledge and their cognitive, computational and physical tools and artifacts. Exploiting the *symmetry of ignorance* as a source of power requires not only a willingness to talk to collaborators, but also externalizations that allow people to think and argue about and that help them to create incrementally a shared understanding of the design problem.

An important technical challenge for *social creativity* is to capture the informal, situated problem-solving episodes that real people generate in solving real problems, which are difficult for formal processes to anticipate or to capture. An important non-technical challenge for social creativity is to take motivation seriously. There must be an incentive to create social capital by rewarding stakeholders to be good citizens by contributing and receiving knowledge as a member of a community [Grudin, 1994].

A necessary, but not sufficient condition for meta-design is that software systems must have advanced features (developed at design time; see Figure 8) that permit complex customizations and extensions by power users and local developers at use time [Nardi, 1993]. *Meta-design* is supported by the seeding, evolutionary growth, reseeding model [Fischer, 1998b]. This process model allows and encourages designers to explicitly underdesign and underprescribe at design time and provide constructs and environments (e.g., Visual AgenTalk and DynaSites, mentioned above) for design support and situated interpretations and actions at use time. In a *closed system*, it is difficult or impossible for users to change the system to deal with new and unforeseen situations. System developers control additions and modifications, and when they are no longer present, the system cannot handle a new situation. This implies that users have to work around or outside such a closed system (or perhaps abandon the system altogether) when they encounter an unexpected situation.

Consumers and Designers. Meta-design is design for designers, not for consumers. By arguing for the desirability for humans to be designers [Fischer, 1998a], it should be stated explicitly that there is nothing wrong with being a consumer. We can learn and enjoy many things in a consumer role (e.g., listening to a lecture, watching a tennis match, or attending a concert). It is a mistake to assume that being a consumer or being a designer has to be a *binary choice*. It is rather a continuum ranging from passive consumer, to active consumer, to end-user, to user, to power user [Nardi, 1993], to domain designer, to medium designer, all the way to meta-designer (see Figure 10, illustrating this finer grain division of labor among software users). Problems occur when someone wants to be a designer but is forced to be a consumer, and when being a consumer becomes a universal habit and mindset that dominates a human life completely.

Consumer<--->Designer

passive consumer

active consumer

end-user

user

power users

domain designer

meta-designer

Figure 10: Beyond Binary Choices

Figure 11 shows the exploitation of the meta-design support built into Microsoft Word with macros. The figure shows two macros: “transpose,” which transposes two characters, and “unwrap,” which unwraps text as shown in the screen image (the same text appears in two forms: in the top half as wrapped text and in the bottom half after the application of the macro in the unwrapped form). As argued above, although end-user programming and modification components are necessary for meta-design environments, they by themselves are far from sufficient. Our empirical investigations have shown that few users take advantage of the end-user modifiability components provided by environments such as Microsoft Word, and even fewer users engage in exchanging their extensions with each others. Other communities (such as the open source code community [Raymond, 1999] and Web-based community of practice [Expert-Exchange, 2000]) are better success examples to be analyzed for meta-design and social creativity.

Our empirical observations and studies have clearly demonstrated that meta-design requires more than just technical facilities. The possibility of extending open systems will not take place within the first few days or weeks of using them, but will require the long-term use of a system by owners of problems engaged in the cultivation of a rich repertoire of personally and socially meaningful artifacts. For example, we do not expect all users to become power users or local developers or to be interested in making radical changes to the system. Their contributions will depend on the perceived benefit of contributing, which involves the effort needed to make changes and the utility received for effecting changes.

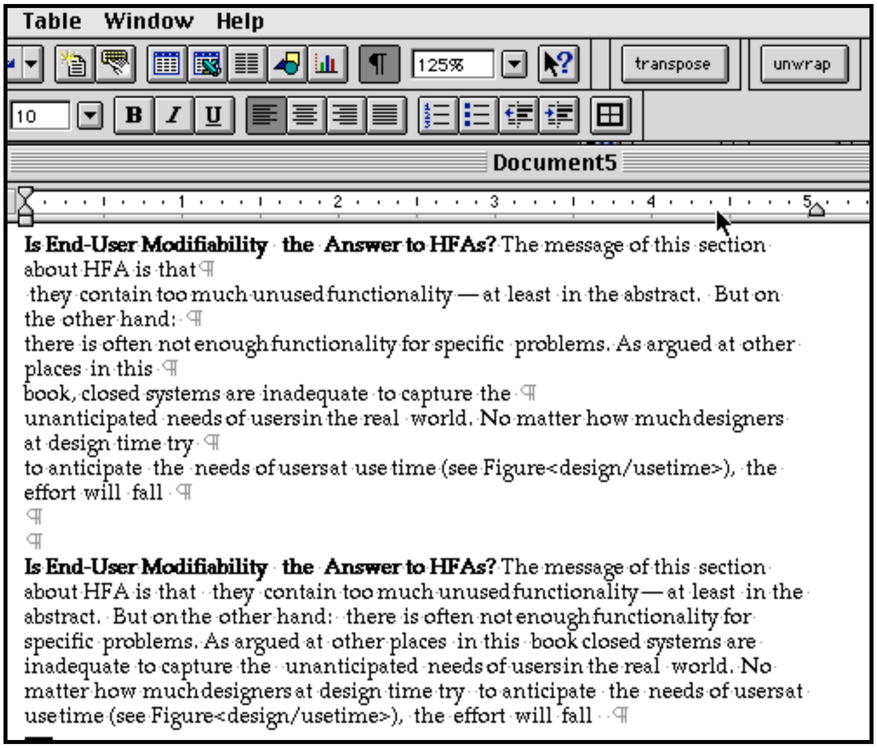

Figure 11: Use of Meta-Design Components in Microsoft Word

CONCLUSIONS

Failing to make computation accessible with reasonable cognitive costs to all people will reduce people's creativity. Furthermore, it will prevent the emergence of computational environments that need to evolve through the active contributions from their users. The three concepts discussed in this paper (symmetry of ignorance, social creativity, and meta-design) provide a conceptual framework for understanding creativity and cognition and for fostering creativity in communities. The paper illustrated the guidance provided by and application of this framework to a number of systems that support social creativity by exploiting the symmetry of ignorance. These systems enhance conversations around shared, mutually understandable artifacts, and they allow stakeholders to learn with and from each other. Such meta-design environments allow stakeholders to act as designers, making it possible to deal with new requirements as they emerge during development, and thereby contributing to the integration of problem framing and problem solving as an important source for social creativity.

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