BEYOND BINARY CHOICES: UNDERSTANDING AND EXPLOITING TRADE-OFFS TO ENHANCE CREATIVITY

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Abstract. Many research approaches are conceptualized as *binary choices*, representing endpoints of a spectrum (each of them providing important perspectives within their own discourses). Design and creativity are often conceptualized as being focused on one of these binary choices, thereby overlooking other possibilities. To better stimulate, enhance, and support creativity, our research has explored the middle ground between the endpoints defined by binary choices to identify "sweet spots" based on a careful trade-off analysis of specific goals, objectives, stakeholders, and socio-technical environments.

This paper illustrates some of the major trade-offs related to design and creativity that we have explored in our research over the last ten years, including prescriptive and permissive environments, individual and social creativity, communities of practice and communities of interest, and consumer and active contributor cultures. It briefly describes some of the socio-technical environments that we have developed to enhance creativity in specific contexts.

Keywords. creativity, individual and social creativity, design, meta-design, binary choices, consumers and producers, communities of practice, communities of interest, domain-oriented design environments, critiquing systems, Envisionment and Discovery Collaboratory, courses-as-seeds

1 Introduction

Our research over the last decade is grounded in *conceptual frameworks* and *system building* efforts characterized by the following global objectives:

- *empowering users rather than replacing or deskilling* them by emphasizing knowledge-based support environments from an intelligence augmentation perspective [Bobrow, 1991; Fischer & Nakakoji, 1992];

- advancing human-computer interaction to human problem-domain interaction, by *putting owners of problems in charge with domain-oriented design environment*s [Fischer, 1994];
- transcending desktop-based computing by *integrating physical and computational environments* [Arias et al., 2000];
- supporting reflective practitioners with critiquing systems by *increasing the back-talk* of design artifacts and linking action and reflection spaces [Fischer et al., 1998; Schön, 1983];
- creating open and evolvable systems grounded in the *seeding, evolutionary growth, reseeding process model* and supported by *meta-design* [Fischer et al., 2004a; Fischer et al., 2001]; and
- understanding design as a *dialectical process between tradition and transcendence* by showing how the tension between old and new in computational artifacts can serve as a driving force of evolutionary developments. Emphasis on tradition reduces the impact of new media to "gift-wrapping," and ignorance of tradition leads to "techno-determinism" [Ehn, 1988; Fischer, 1998].

2 Binary Choices

Trade-offs are the most basic characteristics in design: they are, in fact, universal. There are no best solutions independent of goals and objectives [Simon, 1996]. Trade-offs are often characterized and conceptualized as *binary choices*. Binary choices represent the endpoints of a spectrum (each of them providing important perspectives within their own discourses). Exploring the middle ground between these endpoints, however, will help one to gain a deeper understanding of what stifles and hinders versus stimulates and enhances creativity. Identifying *"sweet spots"* as a combination of factors allowing for a particular suitable solution in a specific context and synergizing the best of the different approaches will enhance further progress. Csikszentmihalyi [Csikszentmihalyi, 1996] discusses personality characteristics of creative people who *"definitely know both extremes and experience both with equal intensity and without inner conflict."* Some examples described by Csikszentmihalyi are (1) being smart and naïve at the same time; (2) a combination of playfulness and discipline, or responsibility and irresponsibility; (3) an alternation between imagination at one end and a rooted sense of reality at the other; and (4) being rebellious and independent, but having internalized a domain of culture.

Creativity is a complex phenomenon, as indicated in part by the personality characteristics mentioned. Any socio-technical environment that supports and enhances creativity must therefore be based on a multi-dimensional framework and architecture. Table 1 provides an overview of some of the major binary choices that we have encountered and tried to overcome in our research (the trade-offs discussed in detail in sections 3.1 – 3.5 of this paper are highlighted in bold).

TABLE 1: Integrating Binary Choices and Finding Partial Resolutions

Choice-1	Choice-2	Choice-3 (Partial Resolution)
tool-based assistance	agent-based assistance	domain-oriented design environments [Shneiderman & Maes, 1997]
generic (“Turing Tar Pit”)	domain-oriented (over-specialized systems)	layered architectures [Fischer, 1994]
tradition	transcendence	dialectical process between the two objectives [Ehn, 1988]
descriptions, requirements	emergence, evolution	seeding, evolutionary growth, reseeding [Fischer et al., 2001]
serendipity	relevancy to the task at hand	provide both and let users choose [Roberts, 1989]
extrinsic motivation	intrinsic motivation	social capital [Florida, 2002]
novice/student/ employee	expert/teacher/manager	collaborative advancement of knowledge [Rogoff et al., 1998]
physical	computational	augmented reality [Arias et al., 2000]
action	reflection	reflection-in-action [Schön, 1983]
discipline	agility	risk-driven approach [Boehm & Turner, 2004]
access (pull; passive critics)	delivery (push; active critics)	mixed-initiative [Horvitz, 1999]
human support	computational support	socio-technical environments [Mumford, 1987]
prescriptive	**permissive**	**guided discovery learning, contextualized tutoring [Mayer, 2004]**
individual	**social**	**integration of individual and social [Fischer et al., 2005]**
communities of practice	**communities of interests**	**epistemological pluralism [Turkle & Papert, 1991]**
consumers (focused on use)	**active contributors (focused on design)**	**end-user development [Fischer, 2002]**
closed systems	**open systems**	**meta-design [Lieberman et al., 2005]**

3 Examples of Trade-Offs

3.1 PRESCRIPTIVE VERSUS PERMISSIVE

Creativity is often associated with transcending the information given and exploring unknown territory. But transcending often implies that we acquire a deep understanding of what exists. People unfamiliar with domains will not develop creative extensions for them [Csikszentmihalyi, 1996]. The prescriptive/permissive trade-off can be explored in several interesting contexts, including: internal and external scripts [Schank & Abelson, 1977]; use of checklists in design environments [Lemke, 1989]; workflow systems in computer-supported collaborative work (CSCW) [Ellis et al., 1991]; and the act of learning and learning environments, which will be used here for further illustration.

Self-directed Learning and Tutoring. One specific area in which the relationship between prescriptive and permissive approaches can be explored is learning. Here we contrast self-directed learning (being primarily permissive, often embedded in constructionist approaches) with tutoring (being primarily prescriptive, often embedded in instructionist approaches). The challenge is to identify a middle ground—learners need enough *freedom* to choose what to learn and how to learn it and enough *guidance* to explore and construct useful knowledge. If pursued independently, self-directed learning and tutoring suffer *shortcomings*. For example, self-directed learning, conceived as pure discovery learning, has the substantial weakness that learners are not exposed to coherent presentations of disciplinary knowledge, and thus remain stuck at suboptimal plateaus. Tutoring, without being contextualized, is not responsive to the real needs and interests of learners.

Tutoring and self-directed learning are grounded in contradictory educational approaches (see TABLE 2):

- *Tutoring* is based on the assumptions that (1) the structure of a discipline is an accumulation of the fundamental ideas that enabled a scholar to proceed [Bruner, 1960]; (2) providing one-to-one instruction is effective [Mandl & Lesgold, 1988]; and (3) society can define a coherent body of knowledge that everyone should master [Hirsch, 1996].
- *Self-directed learning* is based on the assumptions that (1) student interests are central [Dewey, 1967]; (2) people learn best when engrossed in a topic, or when motivated to seek out new knowledge and skills to solve a problem at hand [Csikszentmihalyi et al., 1993; Norman, 1993]; and (3) people in personally meaningful activities want to learn more and act as active contributors, not just as passive consumers [Fischer, 2002].

What is needed but mostly lacking is moving *beyond binary choices*: self-directed learning and tutoring are endpoints in a broad spectrum of possible approaches. Concepts such as *guided discovery learning* [Mayer, 2004] and *community of learners* [Rogoff et al., 1998] illustrate different approaches and show that opportunities exist to exploit the best of both possible worlds.

TABLE 2: Distinctions and Complementary Nature of Tutoring and Self-Directed Learning

	Tutoring	Self-Directed Learning
characteristics	problem is given by the teacher or the systems; learning supported from the supply side; adult-run education; prescriptive	problem is based on the learner's needs and interest; learning supported from the demand side; child-run education; permissive
strengths	organized body of knowledge; pedagogically and cognitively structured presentations	real interests, personally meaningful tasks, high motivation
weaknesses	limited relevancy to the interests of the learner or the task at hand	coverage of important concepts may be missing; demand driven, unstructured learning episodes; lack of coherence
primary role of the teacher	sage on the stage — presents what he/she knows and is prepared for	guide on the side –answers and relevant information have to be culled from questions posed by others
planning versus situated responses	anticipating and planning of the learning goals and content	learning needs arise from the situational context
distribution over lifetime	*decreasing* in importance from school to university to lifelong learning	*increasing* in importance from school to university to lifelong learning
assessment	"standard" assessment instruments are applicable	"innovative" assessment instruments are needed
unique research challenges	presentation of an organized body of knowledge; responsiveness in the teacher-defined context to individual differences	task identification; context awareness; large repository of tutoring episodes

3.2 INDIVIDUAL VERSUS SOCIAL CREATIVITY

The Need for Multiple Voices in Design. Social creativity explores 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, involve designers, programmers, human-computer interaction specialists, marketing people, and end-user participants [Greenbaum & Kyng, 1991]. Information technologies have reached such a level of sophistication, maturity, cost-effectiveness, and distribution that they are not restricted to only enhancing productivity—they also open up new creative possibilities [National Research Council, 2003].

Design projects may take place over many years, with initial design followed by extended periods of evolution and redesign. In this sense, design artifacts are not designed once and for all, but instead they evolve over long periods of time [Fischer, 2005] during which designers may extend or modify artifacts designed by people they 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, collaboration is crucial for success, yet it is difficult to achieve. Complexity arises from the need (1) to synthesize different perspectives, (2) to exploit collisions between concepts and ideas coming from different disciplines, (3) to manage large amounts of information potentially relevant to a design task, and (4) to understand the design decisions that have determined the long-term evolution of a designed artifact. Social creativity does not necessitate the development of environments in which the interests of the many inevitably supersede those of the individual. Appropriate socio-technical settings can amplify the outcome of a group of creative people by both augmenting individual creativities and multiplying rather than simply summing up individual creativities [Fischer et al., 2005].

Individual Creativity. Creative individuals, such as movie directors, leaders of sports teams, and leading scientists and politicians, can make a huge difference in exemplary cases. Individual creativity is grounded in the unique perspective that the individual brings to bear in the current problem or situation. It is the result of the life experience, culture, education, and background knowledge of the individual, as well as the individual's personal interest associated with a particular situation. Individual creativity, however, has limits. In today's society, the Leonardesque aspiration to have people who are competent in all of science has to fail because the individual human mind is limited [Campbell, 2005; Shneiderman, 2002].

Individuals may have the following concerns related to their voices being heard:

"Am I interested enough and am I willing to make the additional effort and time so my voice is heard?" —This relates to what motivates people to participate (e.g., to vote in an election, to engage in a neighborhood association). Participation is more likely in cases in which people are engaged in personally meaningful problems [Fischer, 2002].

"Do I have something relevant to say?" — The local voices and unique expertise are often especially valuable in a global world; the incredible diversity of building styles, restaurants, food, and hotels that exist in different parts of the world are jeopardized and in some cases destroyed by the rise of tourism and the global marketplace [Friedman, 2005].

"Am I able to express what I want to say?" — Owners of problems need to be independent of high-tech scribes; this requires literacy, and in the world today, where ideas and work products are documented with computers, it requires digital fluency [National Research Council, 1999].

"Am I able and willing to express myself in a way that others can understand what I am saying?" — This is relevant in (1) participatory design processes in which people should express themselves with boundary objects [Star, 2005] rather than with their own respective technical jargon, and (2) efforts so the public can understand the work of the scientists.

Social Creativity. Creative activity grows out of the relationship between an individual and the world of his or her work, as well as from the ties between an individual and other human beings. Much human creativity arises from activities that take place in a social context in which interaction with other people and the artifacts that embody group knowledge are important contributors to the process. Creativity happens not inside a person's head, but in the interaction between a person's thoughts and a socio-cultural context [Csikszentmihalyi, 1996].

A group, community, or society is interested in hearing as many voices as possible for the following concerns:

"How can we encourage individuals to contribute to the good and progress of all of us?" — This is relevant in open source efforts, which rely on social capital and gift cultures [Fischer et al., 2004b].

"In order to stimulate and increase social creativity, how can we support and exploit cultural pluralism and epistemological pluralism as an advantage rather than as a disadvantage?" — Related questions include: Is the European multi-culturalism and its local and regional identities a strength or a weakness? Are we willing to accept the validity and the multiple ways of knowing and thinking, especially by including the voices of underrepresented and underprivileged groups (e.g., people with disabilities [Carmien et al., 2004])?

"How do we avoid the situation that voices get lost because there is too much information or their input does not get recorded?" — In other words, how do we create knowledge management environments that support the right

division between pull and push technologies and that have some context awareness?

"How do we avoid illegitimate voices?" — this includes information that is pushed at people without their consent (such as spam mail) or is made available against their will (such as violation of privacy).

"How do we avoid getting stuck in group think?" — This includes seeing controversy as an asset rather than as a limitation; *group think* [Janis, 1972] is especially harmful if some groups believe that their way of thinking is on top, rather than on tap [Turkle & Papert, 1991].

"How do we eliminate sources of exclusion?" — This includes not only rules that specifically exclude people (such as minorities, lay persons facing experts, or people with disabilities), but ways of thinking and organizing that make them reluctant to join in.

Integrating Individual and Social Creativity. Our work is grounded in the basic belief that there is an "and" and not a "versus" relationship between individual and social creativity [Fischer et al., 2005]. Creativity occurs in the relationship between an individual and society, and between an individual and his or her technical environment. The mind, rather than driving on solitude, is clearly dependent upon the reflection, renewal, and trust inherent in sustained human relationships [John-Steiner, 2000]. We need to support this distributed fabric of interactions by integrating diversity, making all voices heard, increasing the back-talk of the situation, and providing systems that are open and transparent, so that people can be aware of and access each other's work, relate it to their own work, transcend the information given, and contribute the results back to the community. This process is illustrated (in part at least) by the *"location, comprehension, and modification"* cycle in software reuse [Ye & Fischer, 2005], the *"collect/relate/create/donate"* model [Shneiderman, 2002], and by the decentralized development process of open source communities [Scharff, 2002].

Individual and social creativity can be integrated by means of proper *collaboration models* [Olson et al., 2001], appropriate *community structures* [Wenger, 1998], *boundary objects* [Star, 2005], *process models* in support of natural evolution of artifacts [Fischer et al., 2001], and *meta-design* [Fischer et al., 2004a]. By integrating individual and social creativity, support will be provided not only for reflective practitioners but also for reflective communities. Even within disciplines, competence is not achieved in individual minds, but as a collective achievement made possible by the overlap of narrow specialties [Campbell, 2005].

3.3 COMMUNITIES OF PRACTICE VERSUS COMMUNITIES OF INTEREST

"The clashing point of two subjects, two disciplines, two cultures ought to produce creative chaos." C.P. Snow [Snow, 1993]

Design communities are increasingly characterized by a *division of labor* [Levy & Murnane, 2004], comprising individuals who have unique experiences, varying interests, and different perspectives about problems, and who use different knowledge systems in their work [Bonifacio & Molani, 2003]. Shared understanding [Resnick et al., 1991] that supports collaborative learning and working requires the active construction of a knowledge system in which the meanings of concepts and objects can be debated and resolved. In heterogeneous design communities that form around large and complex design problems, the construction of shared understanding requires the interaction and synthesis of several separate knowledge systems [Turkle & Papert, 1991].

Diversity is not only a constraint to deal with but an opportunity to generate new ideas, new insights, and new environments [Basalla, 1988; National Research Council, 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 and by exploiting conceptual collisions and breakdowns as sources for innovation.

Communities of Practice (CoPs) [Fischer, 2001b; Wenger, 1998] are *homogeneous* design communities consisting of practitioners who work as a community in a certain domain undertaking similar work. Traditional learning and working environments (e.g., university departments and their respective curricula) are disciplinary. Throughout history, the use of disciplines and their associated development of a division of labor have proven to be powerful approaches. However, we know from all the attempts to support multidisciplinary work that "real" problems can only rarely be successfully approached by a lone discipline [Campbell, 2005; Derry & Fischer, 2005].

Communities of Interest (CoIs) [Fischer, 2001a] are *heterogeneous* design communities bringing together stakeholders from different CoPs to solve a particular (design) problem of common concern. They can be thought of as "communities of communities" [Brown & Duguid, 1991] or communities of representatives of communities. Examples of CoIs are (1) a team of software designers, marketing specialists, psychologists, and programmers interested in software development; or (2) a group of citizens and experts interested in urban planning, in particular, in implementing new transportation systems. CoIs are supported by the *Envisionment and Discovery Collaboratory* [Arias et al., 2000] (see section 4), an integrated physical and computational environment supporting informed participation through new forms of knowledge creation, integration, and dissemination. Fundamental challenges facing CoIs are found in building a *shared understanding* [Resnick et al., 1991] of the task at hand, which often does not exist at the beginning but is evolved 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 [Derry et al., 2005; Engeström, 2001] who have different perspectives and perhaps different vocabularies to describe their ideas in order to establish a common ground [Clark & Brennan, 1991].

Comparing CoPs and CoIs. TABLE 3 characterizes and differentiates CoPs and CoIs along a number of dimensions. The point of comparing and contrasting CoPs and CoIs is not to pigeonhole groups into either category, but rather to identify patterns of practice and helpful technologies. People can participate in more than one community, or one community can exhibit attributes of both a CoI and a CoP.

TABLE 3: Differentiating CoPs and CoIs

Dimensions	CoPs	CoIs
nature of problems	different tasks in the same domain	common task across multiple domains
knowledge development	refinement of one knowledge system; new ideas coming from within the practice	synthesis and mutual learning through the integration of multiple knowledge systems
major objectives	codified knowledge, domain coverage	shared understanding, making all voices heard
weaknesses	group-think	lack of a shared understanding
strengths	shared ontologies	social creativity; diversity; making all voices heard
people	beginners and experts; apprentices and masters	stakeholders (owners of problems) from different domains
learning	legitimate peripheral participation	informed participation

Our Center for LifeLong Learning and Design (L3D) is an example: it has many characteristics of a CoP (having developed its own stories, terminology, and artifacts), but by actively engaging with people from outside our community (e.g., other colleges on campus, people from industry, international visitors, and so forth), it also has many characteristics of a CoI. Design communities do not have to be strictly either CoPs or CoIs; they can integrate aspects of both forms of communities. The community type may shift over time, according to events outside the community, the objectives of its members, and the structure of the membership.

CoPs are biased toward communicating with the same people and taking advantage of a shared background. The existence of an accepted, well-established center of expertise and a clear path of learning toward this center allows the differentiation of members into novices, intermediates, and experts. It makes these attributes viable concepts associated with people and provides the foundation for legitimate peripheral participation as a workable learning strategy. Some limitations of CoPs are that *group-think* [Janis, 1972] can suppress exposure to, and acceptance of, outside ideas; and the more someone is at home in a CoP, the more that person forgets the strange and contingent nature of its categories from the outside.

CoIs have a potential for creativity because different backgrounds and different perspectives can lead to new insights [Bennis & Biederman, 1997]. They can support pluralistic societies by coping with complexity, contradictions, and a willingness to allow for differences of opinion. A fundamental barrier for CoIs might be that the participants fail to create common ground and shared understanding. This barrier is particularly challenging because CoIs often are more temporary than CoPs; they come together in the context of a specific project and dissolve after the project has ended.

3.4 CONSUMER VERSUS PRODUCER CULTURES

The process of knowledge accumulation in society has undergone major changes. Initially, knowledge was accumulated in the heads of people and communicated by tales, stories, and myths. The *oral* tradition has been replaced by a *written* tradition that allows people to permanently record thoughts and widely distribute them [Ong, 1982]. *Information technologies* [Hippel, 2005] have created fundamentally new opportunities, new challenges, and new problems for knowledge creation, integration, and dissemination, including *open source communities* [Fischer et al., 2004b; Raymond & Young, 2001] and *collaboratively constructed online encyclopedias* such as Wikipedia (http://wikipedia.org/). The amount of available information and knowledge is exploding, and because information and knowledge consume attention, we all are suffering from it.

In our research we have developed a number of basic conceptual frameworks to support new ways to accumulate knowledge and selectively distribute it, including:

- the Seeding/Location/Comprehension/Modification/Sharing model instantiated by the Codebroker system [Ye & Fischer, 2005];
- the Seeding/Evolutionary Growth/Reseeding model [Fischer et al., 2001]; and

- the meta-design framework [Fischer et al., 2004a].

These approaches are related to: (1) the collect/relate/create/donate model of Shneiderman [Shneiderman, 2002]; (2) the basic assumption that information has a social life [Brown & Duguid, 2000]; and (3) the ideas of convivial tools and deprofessionalization [Illich, 1973].

Professionally Dominated Cultures. A professionally dominated culture is characterized by a small number of experts and a large number of consumers (see Figure 1). Based on strong input filters (e.g., low acceptance rates for conferences and journals), relatively small information repositories are created. The advantage is the likelihood that the quality and trustworthiness of the accumulated information is high; thus, relatively weak output filters are required. The disadvantage of this model is that it greatly limits that "all voices can be heard," that most people are limited 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.

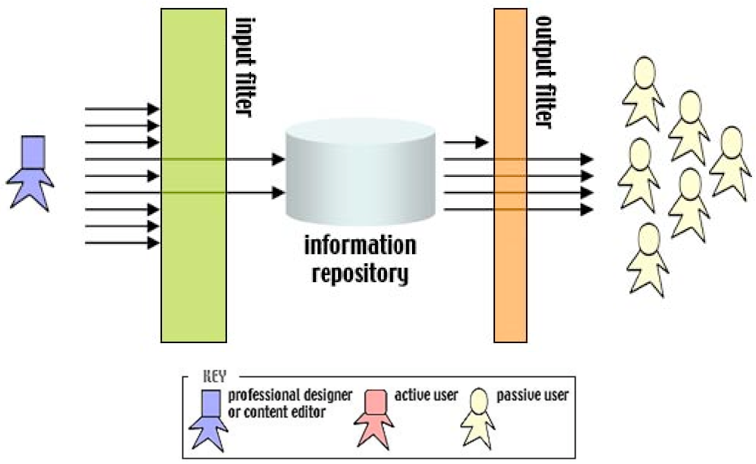

Figure 1: Producer/Consumer Relationships in a Professionally Dominated Culture

Design Cultures. Design cultures can be characterized by weak input filters, which allow users to not only access information but to become active contributors by engaging in *informed participation* [Brown et al., 1994]. The resulting information repositories (see Figure 2) are much larger (the World Wide Web is the prime example of this approach). Major limitations of this model are the potentially reduced trust and reliability of the content of the information repositories. This requires powerful search mechanisms to find relevant information and strong new output filters to allow users to judge the reliability of the information.

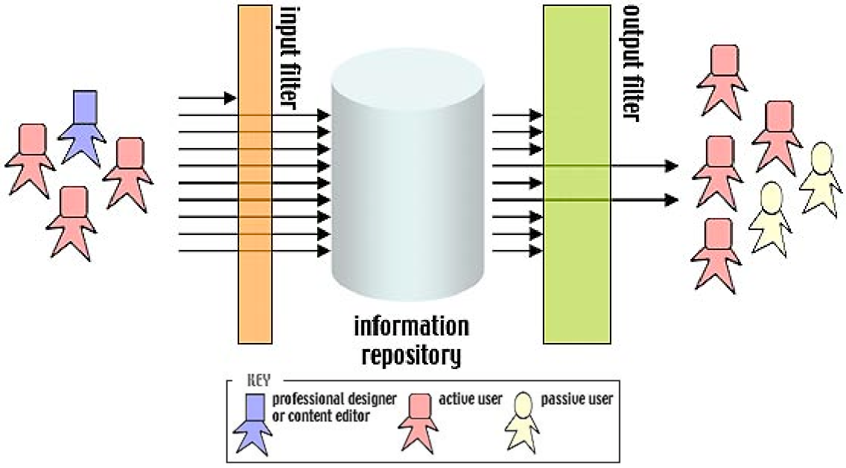

Figure 2: Producer/Consumer Relationships in a Design Culture

This brief characterization of the two models shows that both have strengths and weaknesses, and both serve as the guiding principles in different settings. Figure 3 illustrates how the proceedings of conferences—the CHI conference (white book) using strong input filters and the HCI International conference (dark books) using weak input filters—document their results in very different ways, depending on the basic criteria established by the respective meetings.

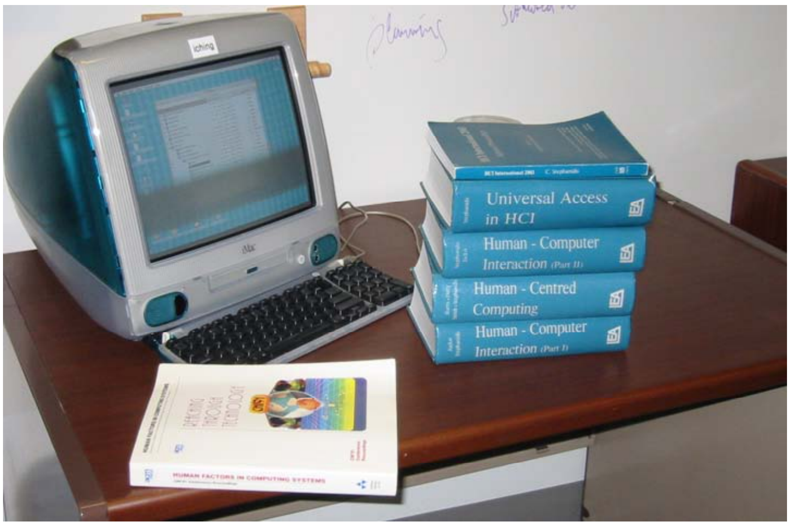

Figure 3: The Proceedings of Two Conferences

3.5 META-DESIGN: BEYOND CLOSED AND OPEN SYSTEMS

Meta-design [Fischer et al., 2004a] characterizes objectives, techniques, and processes to allow users to act as designers by creating new knowledge rather than restricting them to the consumption of existing knowledge. Meta-design allows creative and unplanned opportunism, supports reflective communities, and addresses one of the fundamental challenges of a knowledge society: to invent and design a culture in which all participants in a collaborative design process can express themselves and engage in personally meaningful activities [Hippel, 2005].

The need for meta-design 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 at use time will encounter mismatches between their problems and the support that a system provides. These mismatches will lead to *breakdowns*, which serve as potential sources for new insights, new knowledge, and new understanding. Meta-design advocates a shift in focus from finished products or complete solutions to conditions for users to resolve mismatches and repair breakdowns when they are discovered during use.

Meta-design extends the traditional model of system development consisting of fixed stages to include an ongoing process in which stakeholders become *co-designers*—not only at design time but also throughout the whole existence of the system. A necessary, although not sufficient, condition for users to become co-designers is that software systems include advanced features (direct activation tools and design environments) that permit users to create complex customizations and extensions to existing systems. Rather than presenting users with closed systems, meta-design approaches provide them with opportunities, tools, and social reward structures to extend the system to fit their needs. Moreover, meta-design is a design methodology that involves multiple stakeholders. One of its objectives in its effort to overcome borders is to make all voices heard. An interesting challenge from this point of view is how to integrate the contributing voices originating from *individual and social perspectives*.

Meta-design covers the middle ground between general purpose programming languages (Turing Tar Pit) and over-specialized (turnkey) systems. Users need access to a middle ground of abstractions—lightweight but powerful tools and techniques that shorten the edit-compile-debug cycle of conventional programming. To modify a computer application, users should increase their knowledge only by an amount proportional to the complexity of the modification. This has been conceptualized as the "gentle slope" to programming, providing end-user developers with increasingly complex design environments for making changes.

Our evolving meta-design framework pays attention to motivation, specifically including the following aspects [Fischer et al., 2004b]:

- making changes must seem possible for the skill and experience level of specific users [Scharff, 2002];
- changes must be technically possible (a central objective of our meta-design approach) [Fischer & Giaccardi, 2004];
- benefits must be perceived; that is, individuals must perceive a direct benefit in contributing that is large enough to outweigh the effort [Grudin, 1987];
- the effort required to contribute must be minimal so that it will not interfere with getting the real work done [Carroll & Rosson, 1987].

Social creativity needs the "synergy of many," and this kind of synergy is facilitated by meta-design. However, a tension exists between creativity and organization. A defining characteristic of social creativity is that it transcends individual creativity and thus requires some form of organization. On the one hand, elements of organization can and frequently do stifle creativity [Florida, 2002]. On the other hand are historical precedents that *too many voices* can be worse than having a few choices. As a prime example, the multiparty system that existed in the Weimar Republic in Germany after World War I created a less stable political system compared to countries with a limited number of political parties.

The open systems created by metadesign (a) promote the transcendence of the individual mind; (b) support the users' engagement in the collaborative construction and sharing of meaningful activities; and (c) enable the mutual adaptation and continuous evolution of users and systems by letting users modify the system at use time and adapt it to their dynamic practices.

4 Socio-Technical Environments: Exploiting Trade-Offs to Enhance Creativity

In the last decade, L3D has developed *socio-technical environments* to support the partial resolutions between the binary choices indicated in Table 1. Socio-technical environments can be characterized as follows: (1) They are needed because the deep and enduring changes of our ages are *not technological but are social and cultural, in their core substance.* Changes in complex environments are not primarily determined by technology, but are the result of incremental shifts in human behavior and social organization. (2) They are composed *not only* of computers, networks, and software, *but also* of people, processes, policies, laws, institutions, the flow of design materials and commodities, and many other aspects of a complex web of socio-cultural concerns. (3) They require a *co-design* of social and technical systems and use models and concepts that not only focus on the artifact, but exploit the social context in which the systems will be used. Meta-design is a critical component for socio-technical environments because it gives the users design power to modify and evolve the technical systems according to their needs. The following brief examples of socio-technical environments deal with specific binary choices and their respective solutions (in reference to Table 1).

Domain-oriented design environments [Fischer, 1994] integrate construction and argumentation. They support CoPs by allowing them to interact at the level of the problem domain and not only at a computational level. They allow for efficient communication within the community at the expense of making communication and understanding difficult for outsiders. They integrate tool-based assistance (e.g., direct manipulation interfaces with objects grounded in the semantics of the problem domain) with agent-based assistance (e.g., critics and simulation components).

Computational critiquing mechanisms [Fischer et al., 1998] enrich the back-talk of situations, thereby increasing the users' understanding of problems by pointing out significant design situations and locating relevant information in large information spaces. Critics afford learning on demand by letting designers access new knowledge in the context of actual problem situations. Critics instantiate and transcend Schön's theory of design [Fischer & Nakakoji, 1992]; they support "reflection-in-action" and they increase the "back-talk" of the design situation, which in Schön's framework is determined by the designers' skill, experience, and attention [Schön, 1983]. Critics explore and support the trade-offs between (1) serendipity and relevance to the task at hand, (2) information access and information delivery, and (3) new collaboration models between human and computational support.

The Envisionment and Discovery Collaboratory [Arias et al., 2000] supports CoIs with an environment in which participants collaboratively solve problems of mutual interest. The problem contexts explored in the collaboratory, such as urban transportation planning, flood mitigation, and building design, are all examples of open-ended design problems. The socio-technical environment empowers users to act as designers in problem-solving activities by supporting face-to-face collaboration (see Figure 4). It allows users to engage in complex design tasks by supporting them to incrementally articulate their ideas and negotiate with each other to create mutually agreeable design plans. With the Envisionment and Discovery Collaboratory, new relationships between individual and social creativity [Fischer et al., 2005] can be explored.

Figure 4: The Envisionment and Discovery Collaboratory

CodeBroker [Ye, 2001] (a reuse support system specifically addressing temporal distance) creates awareness of each other's work so that efforts are not wasted and people can focus on what has not been done before. CodeBroker monitors software developers' programming activities, infers their immediate programming task by analyzing semantic and syntactic information contained in their working products, and actively delivers task-relevant and personalized reusable parts [Fischer et al., 1998] from a reuse repository created by decomposing existing software systems. CodeBroker will be further developed as an open source software system [Raymond & Young, 2001] to support the collaboration of a large number of developers. CodeBroker explores our integrated approaches of reflection-in-action, mixed-initiative interactions, and socio-technical environments.

Courses-as-Seeds [dePaula et al., 2001] is an educational model with the goal to create a culture of informed participation that is situated in the context of university courses and yet extends beyond the temporal boundaries of semester-based classes. Courses are conceptualized as seeds, rather than as finished products, and students are encouraged and supported as knowledge workers who play an active role in defining what they will learn. From the courses-as-seeds standpoint, the role of technology is to form and sustain active communities of learners who can make their voices heard by contributing ideas from their own unique viewpoints and to connect them in new ways. From this perspective, mere access to existing information and knowledge (e.g., seeing courses as finished products, either in the classroom or on the Web) is a very limiting concept. The courses-as-seeds framework explores issues and challenges associated with meta-design, the trade-offs between consumer and producer cultures (see Figure 1 and Figure 2), and the synergy between individual and social creativity.

5 Conclusions

Creativity is a multi-faceted concept. Creative people often combine personality traits that are in conflict with each other [Csikszentmihalyi, 1996]. Socio-technical environments enhancing creativity must support not only one end of the spectrum of binary choices, but also—depending on the domain, tasks, and objectives of the people—must exploit trade-offs in a situated fashion to come as close as possible to the “sweet-spot” for a particular situation. This paper has described some of the trade-offs that we have explored in our research over the last decade and the systems that we have built to gain a deeper understanding of creativity and to support creative people.

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