Meta-Design: Transforming and Enriching the Design and Use of Socio-Technical Systems

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Abstract

The meta-design of socio-technical systems (STS) is an approach which complies with the need of integrating two different types of structures and processes: *technical systems* which are engineered to provide anticipatable and reliable interactions between users and systems, and *social systems* which are contingent in their interactions and a subject of evolution. Meta-design is focused on objectives, techniques and processes to allow users to act as designers. In doing so, it does not provide fixed solutions but a framework within which *all stakeholders* (designers and users) can contribute to the development of technical functionality and the evolution of the social side such as organizational change, knowledge construction, and continuous learning.

This paper describes the possibilities of transforming and enriching the design and use of STSs grounded in the conceptual framework of meta-design. It explores cultures of participation, seeding, evolutionary growth and reseeding, and underdesign as specific components of the framework. Two specific examples of meta-designed STSs illustrate the conceptual framework and findings derived from the assessment of these developments in practice are briefly discussed. Based on the combination of conceptual and methodological consideration, initial guidelines for the meta-design of STSs are derived.

Keywords

socio-technical systems (STSs); design methodologies; participatory design; meta-design; cultures of participation; seeding, evolutionary growth, and reseeding (SER) model; underdesign; contingency; Envisionment and Discovery Collaboratory; Memory Aiding Prompting Systems; design guidelines

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1 Introduction

New technologies and new media are important driving forces and prerequisites to address the complex and systemic problems our societies face today. But technology alone does not improve social structures and human behavior, making the design of *socio-technical systems (STSs)* [Herrmann, 2003; Mumford, 2000; Trist, 1981] a necessity rather than a luxury.

A unique challenge faced in focusing on STSs is that that they combine two types of fundamentally different systems:

- *Technical systems* that are produced and continuously adapted to provide a reliable, anticipatable relationship between user input and the system's output. This relationship is engineered to serve the needs of users and is preplanned.
- *Social systems* that are the result of continuous evolution including emergent changes and behavior. The development of their characteristics cannot be planned and controlled with respect to the final outcome; the changes within STSs are a matter of *contingency* [Luhmann, 1995]. They can only—if ever—be understood afterwards and not in advance; social systems mainly serve their own needs and not those of others.

The strength of STSs is that they integrate these different phenomena so that they increase their performance reciprocally. Even more important, the integration of technical and social systems helps them to develop and to constitute each other, for example, the interaction among community members is supported by technical infrastructure, and the members themselves can contribute to the development of the infrastructure (as it is, for example, demonstrated by open source communities). However, the relationships between the development of the social and the technical are not deterministic but contingent. For example, developing software for specific organizations does not deterministically change them but only influences the evolution of their social structures. Software designers can be reflective with respect to the impact of a software system on its social context, and they can make their assumptions about the expected evolution of the social system explicit and a matter of discourse, but they cannot control the organizational change.

One emerging unique opportunity to make a systematic and reflected contribution to the evolution of social structures in STSs is *meta-design* [Fischer & Giaccardi, 2006], representing a design methodology supporting the evolution of systems that have contingent characteristics. Whereas many design activities aim to develop concrete technical solutions, meta-design provides a *framework* within which STSs can be developed. Focusing meta-design on the development and evolution of STSs gives the opportunity for a more detailed reflection of methodological implications and guidelines. Meta-design of STSs leads to new considerations that complement traditional participatory design, end-user-programming, or previous principles for the design of STSs.

The paper discusses our understanding of STSs and meta-design. In our analysis, we draw on a body of literature and on a variety of concepts that stem from an interdisciplinary background, such as the interdependence between technology and organization [Orlikowski, 1992], sociological systems theory [Luhmann, 1995], wicked problems [Rittel & Webber, 1984], participatory design [Kensing & Blomberg, 1998], and end-user development [Lieberman et al., 2006].

We describe several different theoretical approaches (cultures of participation, the SER model, and the underdesign methodology) being relevant for the integration of STSs and meta-design. These theoretical considerations are complemented with insights derived from concrete examples that we have developed in our research. Based on the theoretical analysis and the reflection of practical cases, we provide a short list of guidelines for transforming and enriching the design and use of socio-technical systems with meta-design. The concluding section summarizes the reasons for a meta-design approach in the context of socio-technical systems.

The paper represents a condensed (in some parts) and extended (in other parts) version of a paper entitled "Socio-Technical Systems: A Meta-Design Perspective" published earlier by the two authors [Fischer & Herrmann, 2011].

2 Socio-Technical Systems (STSs)

2.1 Characteristics of STSs

Socio-technical systems can be understood as the systematic integration of two kinds of phenomena that have very diverging, partially contradictive characteristics. STSs are composed *both* of computers, networks, and software, *and* of people, procedures, policies, laws, and many other aspects. STSs therefore require the *co-design* of social and technical systems [Herrmann, 2009].

Whereas *technical systems* are purposeful artifacts that can reliably and repeatedly be used to support human needs and to enhance human capabilities, *social systems* are dedicated to purposes that lay within themselves and are a matter of continuous change and evolution, which makes their behavior difficult to anticipate. Social structures can be identified on several levels: communicative interaction between people or in small groups such as families or teams, organizations or organizational units, communities, or social networks. The reactions of social systems to their environment are contingent—they are not independent from external stimuli, but they also are not determined by them. As opposed to necessity, universality, constancy, and certainty, *contingency* [Pedersen, 2000]:

- refers to variability, particularity, mutability, and uncertainty;
- implies that the system creates its own necessity in its pattern of reactions toward events; and
- provides a basis for continuous evolution, including opportunities for emergent changes.

How new phenomena will emerge in social systems cannot be predicted or made the result of a well-planned, algorithmically organized procedure; they depend on coincidences and are context related in the sense of *situatedness* [Suchman, 1987]. Technical systems may also react contingently toward their users, but the more mature a technical system has become, the more one will expect that it is reliable for the users, predictable, and noncontingent. Obviously, the socio-technical perspective covers more aspects than the viewpoint of human-computer interaction (HCI): it is about the relationship between technical infrastructure as a whole and structures of social interaction, which cover organizational and coordination issues, sense making and common ground as a basis for communication, power relations, negotiation, building of conventions, and so forth.

It is not unlikely that formal communication, anticipatable procedures, scripts, and prescriptions may be empirically observable within in social systems. For example, workflow management systems [Herrmann & Hoffmann, 2005] demonstrate the managerial attempt to implement scripts and institutionalize plan-oriented behavior in the context of organizations. However, it is a social system's dominant characteristic that rules and routines can be revised and become subjects of negotiation, and it cannot be predicted whether and when anticipatable behavior is no longer sustained but becomes a subject of evolutionary or emergent change.

By contrast to those researchers who assume that complex human activities can also be assigned to technical systems [Latour, 1999], we suggest that the crucial characteristics of social versus technical systems point in two opposite directions (Table 1). The strength of socio-technical systems results of the *integration* of these two kinds of different phenomena.

Table 1: ***Main Characteristics of Technical and Social Systems***

	Technical systems	Social systems
Origins	Are a product of human activity; can be designed from outside.	Are the result of evolution, cannot be designed but only *influenced* from outside.
Control	Are designed to be controllable with respect to pre-specified performance parameters.	Always have the potential to challenge control.
Situatedness	Low: preprogrammed learning and interaction with the environment.	High: includes the potential of improvisation and non-anticipatable adaptation of behavior patterns.
Changes	Are either preprogrammed so that changes can be autonomously conducted but are anticipatable, or are a result of interventions from outside (so that a new version is established).	Evolutionary: gradual accumulation of small, incremental changes, which can lead to emergent changes (which, however are not anticipatable). There is no social system that can simulate the changes of another social system.
Contingency	Are designed to avoid contingency; the more mature a version is, the less its reactions appear as contingent.	The potential for change and evolution is based on contingency.
Criteria	Correctness, reliability, unexpected, unsolicited events are interpreted as malfunction.	Personal interest, motivation; in the case of unsolicited events, intentional malpractice may be the case.
Modeling	Can be modeled by describing how input is processed and leads to a certain output.	Models can only approximate the real behavior and have continuously to be adapted.

2.2 Beyond Coincidental Connectedness: The Need for Systematic Integration

STSs are more than a coincidental connectedness of technical components and people. STS research is not just applying sociological principles to technical effects, but it explores how social and technical aspects integrate into a higher-level system with emergent properties.

The synergy between technical and social systems can be achieved only if both parts are closely integrated. One of the important theoretical challenges with respect to STSs is to explain how this integration can happen, by which factors it is influenced, and how it can be observed. Sociologists such as [Luhmann, 1995] and [Habermas, 1984] identify *communication*, amongst all kind of human activities, as the most relevant constituent of social systems. Our research emphasizes the role of communication when we try to understand the integration between social and technical structures. The degree of integration between social and technical structures increases with the extent of the following factors.

- Communication that uses the *technical systems as a medium* helps to convey communicational acts and shapes them.
- Communication *about the technical system* includes how it is used, how it has to be maintained, how it could be adapted to the needs of an organization and its users, how its

effects can be compared with other technical systems, and so forth. This kind of communication leads to what we can call the appropriation of the technical system by the social system. The communication mirrors the organization's understanding of the technical structures.

- Content or social structures (e.g., responsibilities or access rights) *regulating communication* are being represented within the technical system as well as the social structures.
- Self-description describes and constitutes the characteristics of the STSs and can be found in the oral communication and in the documents of the social system as well as in the technical system's content and structures [Herrmann et al., 2007].

Within the large set of areas where socio-technical integration takes place, this paper focuses on the design of technical systems that are related to information processing and software development. To determine a clear focus with respect to the social structures into which technical systems are integrated proves difficult. The classical socio-technical literature [Trist, 1981] usually addresses the meso-level, concerning such organizations as companies, administrations, and non-government organizations (NGOs) or their subunits. However, with the emergence of the web, and in particular Web2.0 and social software, phenomena have to be taken into account such as virtual communities, which form larger units between the middle- and the macro-level where individuals and/or several companies are interacting within new social structures that became possible only by new types of technical infrastructure. The new phenomena that emerged in the context of the web and Web2.0 also gave new reasons for intensifying socio-technical analyses and approaches. It also became obvious that socio-technical phenomena cannot always be appropriately described by the concept of "closed system" as it is defined by [Maturana & Varela, 1980]. By contrast, it can be more adequate to focus the analysis on *socio-technical environments* [Carmien & Fischer, 2008] within which the integration of technical and social structures can develop. Such a socio-technical environment is less the result of engineering or design activities and more a context within which design takes place and is intertwined with the evolutionary growth of social structures.

With respect to their evolution, socio-technical systems integrate two characteristics: on the one hand, they are the result of such human activities as design, engineering, managing, communication, learning, and continuous improvement; on the other hand, they serve on a higher level as the environment or framework within which these kind of human activities take place. Therefore we argue that the concept of "meta-design" is more appropriate to describe how socio-technical systems are developed and do develop.

3 Meta-Design: Enriching the Ecology of Design Methodologies

3.1 Established Design Methodologies

In all design processes two basic stages can be differentiated: *design time* and *use time*. The established design methodologies are primarily related to design time: System developers (with or without user participation) create environments and tools for the world as *imagined* by them to anticipate users' needs and objectives. They engage in formal and intentional design activities targeted towards the creation of artifacts or systems as imagined. They engage in planning activities guided by the predicted needs of future user populations.

At *use time*, users will use the system. Their activities are shaped by a world as *experienced*, they are able to deal with a world as experienced and planning is enriched by situated actions. but because their needs, objectives, and situational contexts can only be anticipated at design time, the system often requires modification to fit the users' needs [Henderson & Kyng, 1991].

The need to empower users as designers and active contributors is not a luxury but a necessity: computational systems modeling some particular "world" are never complete; they must evolve over time because (1) the world changes and new requirements emerge; and (2) skilled domain professionals change their work practices over time—their understanding and use of a system will be very different after a month and certainly after several years. If systems cannot be modified to support new practices, users will be locked into existing patterns of use.

The following established *design methodologies* [Ye & Fischer, 2007] can be differentiated (with respect to: which stakeholders are present at design and use time, which information do they take into account, and which activities do they carry out):

- **Professional Design.** Early digital artifacts were developed by professionals without too much concerns about users. This was an adequate design methodology at the time, because the users were computer professionals and the designers lived in the same "world" as the users.
- **User-Centered Design.** As digital artifacts became more ubiquitous and users were not only computer professionals but came from all disciplines, *user-centered design* [Norman & Draper, 1986] complemented professional design. Designers (with the help of ethnographers) studied use community and derived design criteria characterizing the world of different use communities.
- ***Participatory design*** approaches [Kensing & Blomberg, 1998; Schuler & Namioka, 1993] seek to involve users (or user representatives) more deeply in the process as co-designers at design time by empowering them to propose and generate design alternatives themselves (see Figure 1). Participatory design (characterized as *"design for use before use"* in [Binder et al., 2011]) supports diverse ways of thinking, planning, and acting by making work, technologies, and social institutions more responsive to human needs. It requires the social inclusion and active participation of the users. Participatory design has focused on system development at design time by bringing developers and users together to envision the contexts of use.

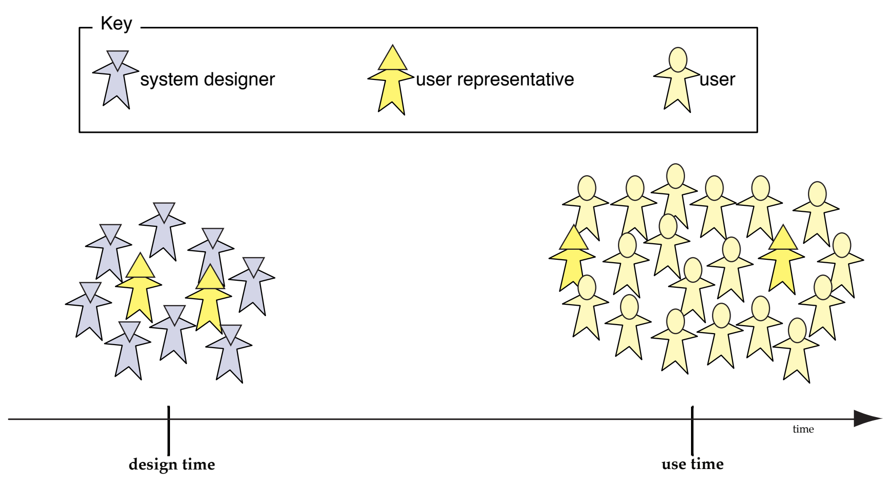

Figure 1: Design and Use Time — Roles and Involvements in Participatory Design

The three design methodologies described above focused primarily on activities and processes taking place at design time in the systems' original development, and have given little emphasis and provided few mechanisms to support systems as living entities that can be evolved by their users.

But despite the best efforts at design time, systems need to be evolvable to fit new needs, account for changing tasks, deal with subjects and contexts that increasingly blur professional and private life, couple with the socio-technical environment in which they are embedded, and incorporate new technologies [Henderson & Kyng, 1991].

3.2 Meta-Design

Meta-design [Fischer & Giaccardi, 2006] provides the enabling conditions for putting owners of problems in charge by defining the technical and social conditions for broad participation in design activities. It addresses the challenges of fostering new mindsets, new sources of creativity, and cultural changes to create foundations for innovative societies.

Meta-design is an emerging conceptual framework aimed at defining and creating socio-technical systems or environments and at understanding both as living entities. It extends existing design methodologies focused on the development of a system at design time by allowing users to become co-designers at use time. Meta-design (see Figure 2); characterized as *"design for design after design"* in [Binder et al., 2011]) is grounded in the basic assumption that future uses and problems cannot be completely anticipated at design time, when a system is developed [Suchman, 1987; Winograd & Flores, 1986]. At use time, users will discover mismatches between their needs and the support that an existing system can provide for them. Meta-design *extends boundaries* by supporting users as active contributors ("users-as-designers") who can transcend the functionality and content of existing systems. By facilitating these possibilities, *control* is distributed among all stakeholders in the design process.

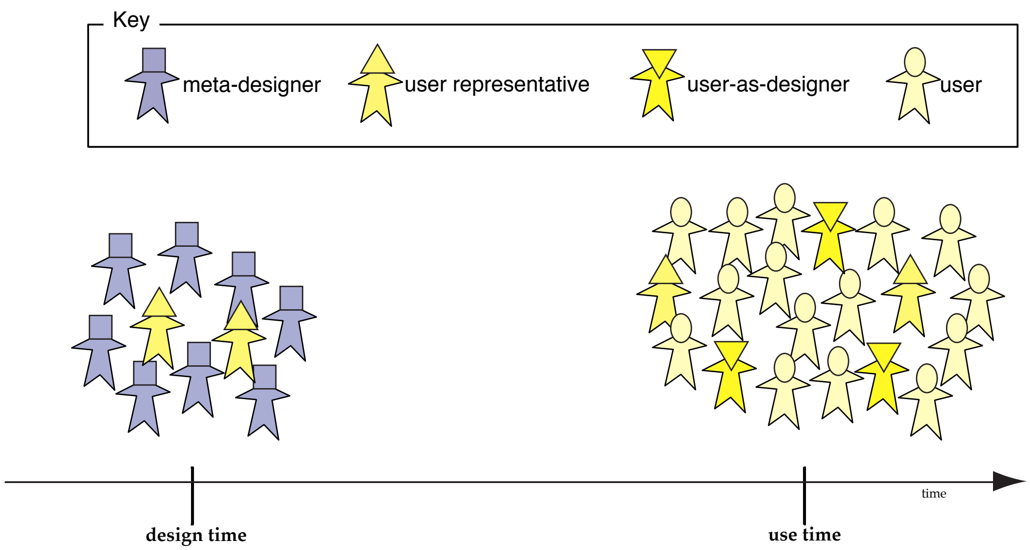

Figure 2: Design and Use Time — Roles and Involvements in Meta-Design

Meta-design integrates approaches, which comprise objectives, techniques, representations of concepts, boundary objects, and processes for creating new media and environments that allow "owners of problems" as members of a social system to act as *designers*. A fundamental objective of meta-design is to establish a basis for the creation of STSs that empower all relevant stakeholders of groups, communities of practice, communities of interest, and organizations to engage actively in the *continuous development* of a concrete socio-technical solution rather than being restricted to a prescribed way of interacting with the technical system or with its users.

The crucial aspect of meta-design, which leads to its name, is that of "*designing design*" [Fischer & Giaccardi, 2006]). This refers to the concept of higher-order design, and the possibility of a malleability and modifiability of structures and processes as provided, supported, or influenced by computational media. It is a design approach that focuses on a framework of general structures and processes, rather than on fixed objects and contents, and rules.

The meta-design objective of "designing design" supports IT-developers to overcome the following dilemma: On the one hand a successful usage of software does not only rely on its technical features but also on the development of appropriate organizational processes and structures representing the context of the software's application. Therefore, meta-designers should not solely focus on technology but also support managers and those who are in charge with organizational development. On the other hand, organizational structures and processes evolve by the activities, routines, and decisions of people, and are not a subject of design methods which are usually focused on artifacts. However, meta-designers can develop a framework (in participatory design efforts with domain experts) that allows its users to intertwine the design of technical systems and the development of appropriate organizational structures and procedures to integrate them into a socio-technical system. A typical example for this objective are features that support the specification of rules for accessing data or documents. On the basis of those features, users can develop their own organizational rules for accessing information and implement them with the help of support mechanisms provided by the meta-designers. "Designing design" does therefore not only support technical modifications but also provides a framework for the development of additional organizational features.

4 Components of the Conceptual Framework

4.1 Cultures of Participation

Cultures are defined in part by their media and their tools for thinking, working, learning, and collaborating. In the past, the design of most media emphasized a clear distinction between producers and consumers [Benkler, 2006]. In a similar manner, our current educational institutions often treat learners as consumers, fostering a mindset in students of "consumerism" rather than "ownership of problems" for the rest of their lives. As a result, learners, workers, and citizens often feel left out of decisions by teachers, managers, and policymakers, denying them opportunities to take active roles.

The rise in *social computing* (based on social production and mass collaboration) has facilitated a shift from *consumer cultures* (specialized in producing finished artifacts to be consumed passively) to *cultures of participation* (in which all people are provided with the means to participate and to contribute actively in personally meaningful problems) [Fischer, 2011]. These developments represent unique and fundamental opportunities, challenges, and transformative changes for innovative research and practice in socio-technical systems as we move away from a world in which a small number of people define rules, create artifacts, make decisions for many consumers towards a world in which meta-design environments support everyone to actively participate.

Our research is exploring *theoretical foundations* and *system developments* for understanding, fostering, and supporting *cultures of participation* grounded in the basic assumption that innovative technological developments are *necessary* for cultures of participation, but they are *not sufficient*. Socio-technical environments are needed because cultures of participation are not dictated by technology: they are the result of changes in human behavior and social organization in which active contributors engage in innovative design, adoption, and adaptation of technologies to their needs and in collaborative knowledge construction. While cultures of participation are dependent on interactive technologies, they are also different: interactivity is a property of the technology, while participation is a property of culture. A sole focus on expanding access to new technologies is limited if we do not also foster the skills and cultural knowledge necessary to deploy those tools toward our own ends.

Meta-design supports and requires cultures of participation by allowing people with different competences (in application domains, in media) to contribute to socio-technical solutions. *Cultures of participation* are facilitated and supported by a variety of different technological environments (such as: the participatory Web ("Web 2.0") [O'Reilly, 2005], table-top computing, and domain-oriented design environments); all of them contributing in different ways to the aims of engaging diverse audiences, enhancing creativity, sharing information, and fostering the collaboration among users acting as active contributors and designers. They democratize design and innovation [von Hippel, 2005] by shifting power and control towards users, supporting them to act as both designers and consumers ("prosumers") [Tapscott & Williams, 2006] and allowing systems to be shaped through real-time use. Meta-design supports the inclusion of user-generated content in cultures of participation, in which "content" is broadly defined as: (a) creating artifacts with existing tools or (b) changing the tools. In specific environments, such as open source software, the content is subject to the additional requirement of being computationally interpretable.

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

The SER model [Fischer & Ostwald, 2002] (see Figure 3) was developed as a descriptive and prescriptive model for creating systems that best fit an emerging and evolving context. In the past, large and complex systems were built as complete artifacts through the large efforts of a small number of people. Instead of attempting to build complete systems, the SER model advocates building seeds that change and grow, and can evolve over time through the small contributions of a large number of people. The seeds play the role of *boundary objects* [Star, 1989], to which the communication between involved people can refer. SER postulates that systems that evolve over a sustained time span must continually alternate between periods of planned activity and unplanned evolution, and periods of deliberate (re)structuring and enhancement.

The SER model encourages designers to conceptualize their activity as meta-design, thereby aiming to support users as active contributors. The applicability, feasibility, and usefulness of the SER model have been demonstrated in the context of several STSs (including the two described in Section 5).

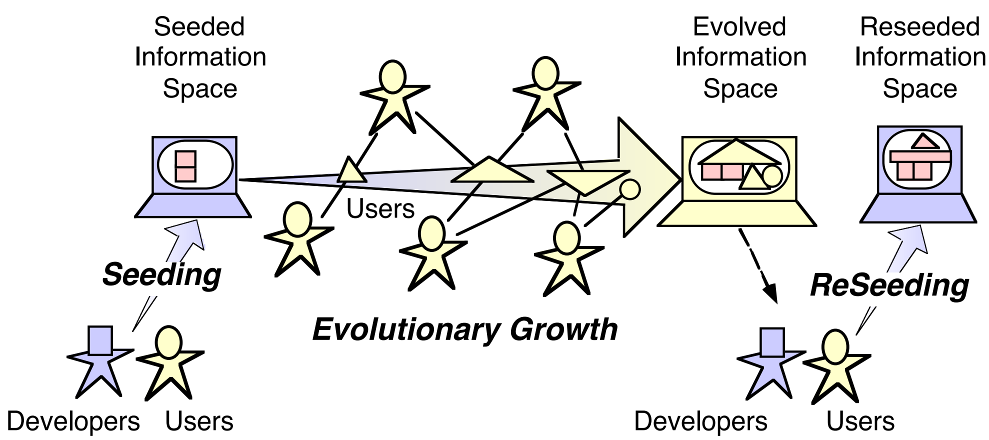

Figure 3: The Seeding, Evolutionary Growth, and Reseeding (SER) model

Meta-design provides methods and practices that support seeding and evolutionary growth. SER works only in the context of the other principles of meta-design such as participation, underdesign, and empowerment for adaptation. Similar to action research [Avison et al., 1999] or the behavior of reflective practitioners [Schön, 1983], phases of experimenting and practicing have to alternate with phases of reflection during the evolutionary growth. Transferring the SER model to STSs implies that seeds are built not only for technical features but also for social structures and interactions. The growth of the seeds (for both the technical and social dimensions) cannot be anticipated at design time. How seeds will evolve or are used is situated in future uses at use time and cannot be sufficiently planned at design time.

Developments conceptualized with the SER model see the "unfinished" as an opportunity rather than as an obstacle or as something to be avoided. It is grounded in the basic assumption that for most real-world systems "design time" and "use time" should not be totally separated and suggests a more complex relationship between these different phases.

4.3 Underdesign

To accommodate unexpected issues at use time, systems need to be underdesigned at design time. *Underdesign* [Brand, 1995; Habraken, 1972] in this context does not mean less work and fewer demands for the design team, but it is fundamentally different from creating complete systems. The primary challenge of underdesign is to develop not solutions but environments that allow the *"owners of problems"* [Fischer, 2002] to create the solutions themselves at use time. This can be done by providing a context and a background against which situated cases, coming up during use time, can be interpreted. Underdesign is a defining activity for meta-design aimed at creating design spaces for others. It assumes that the meaning, functionality, and content of a system are not fully defined by designers and user-representatives alone at design time, but are socially constructed throughout the entire design, deployment, and use cycles of the system. Underdesign is based on the following design principles and mechanisms:

- it is grounded in the need for "loose fit" in designing artifacts at design time so that unexpected uses of the artifact can be accommodated at use time; it does so by creating contexts and content-creation tools rather than focusing on content alone;
- it avoids design decisions being made in the start of the design process, when everyone knows the least of what is needed;
- it offers users (acting as designers at use time) as many alternatives as possible, avoiding irreversible commitments they cannot undo (one of the drawbacks of overdesign);
- it acknowledges the necessity to differentiate between structurally important parts for which extensive professional experience is required and therefore not be easily changed (such as structure bearing walls in buildings); and components which users should be able to modify to their needs because their personal knowledge is relevant; and
- it creates technical and social conditions for broad participation in design activities by supporting mechanisms for adaptation, remixability, and evolution at use time by offering functionality for tailorability, customization, and user-driven adaptability [Morch, 1997].

With respect to social structures, the American Constitution can be considered as one of the biggest success cases for underdesign [Simon, 1996]. Written over 200 years ago and updated by only a small number of amendments, it still serves as a foundation for the United States of America in a world that has changed dramatically.

Underdesign in the context of STS not only refers to hardware and software but also to the plans that describe how the technology will be used and how the collaboration of the users is coordinated. The most prominent examples of representing this kind of plan are process models. They can be overdesigned, as in the case of models that are developed to implement organizational prescriptions by programming workflow management engines. Preprogrammed workflow management systems force the users into inflexibility, which causes problems in handling exceptions or improvising a solution, for example. Conversely, it is not reasonable to go without explicit process models because they help people within an STS explain the need for changes to others, introduce newcomers to the STS, or document changes that have taken place so that evolutionary growth is supported [Smith, 1997]. The solution pursued by our research team is the *modeling method "SeeMe"* [Herrmann et al., 2004] supporting underdesign with flexible degrees of incompleteness and impreciseness.

SeeMe was developed to support the drafting of organizational plans that mix prescriptions with space for free decisions [Fischer & Herrmann, 2011]. The following examples can frequently be observed in practical cases:

- There is a mix of two types of decisions in the course of tasks: (1) the first type can be freely made by users who are carrying out the tasks, and (2) the second type is made by others such as superiors or quality management representatives. With increasing experience the control by others becomes more and more irrelevant and is often only a subject of formal execution. Flexible planning allows the organization to react on the increase of competencies. For example, in the case of collaboratories (see Section 5.1) users who did not dare to modify the features without the help of others will start to do this after a period of growing confidence.

- Activities can either be carried out in a prescribed sequence or in a sequence that is specified by those who carry out the work. In many cases sequences are prescribed although they do not represent the most efficient procedures. Similarly, organizational planning requires in many cases that a certain task is completed before the next one can start despite the fact this requirement is very often unnecessarily inflexible.
- Adaptation of a plan at use time can be an activity that is part of the plan developed at design time. The meta-designers can specify when and under which conditions such a replanning should take place.

Another approach towards underdesign are environments for *open systems* and *open design spaces* [Budweg et al., 2009], which are systems focused on the "unfinished" and take into account that design problems have no stopping rule, need to remain open and fluid to accommodate ongoing change, and for which "continuous beta" becomes a desirable rather than a to-be-avoided attribute.

5 Examples of Meta-Designed STSs

As indicated in Section 3.3, the principles of meta-design have been applied in numerous projects. The two projects described in this section illustrate the meta-design of STSs in two different domains: decision making environments for urban planning and support system for cognitively disabled persons.

5.1 The Envisionment and Discovery Collaboratory (EDC)

The EDC [Arias et al., 2001] is a long-term research platform that explores conceptual frameworks for new paradigms of learning in the context of design problems. It represents a STS supporting reflective communities by incorporating a number of innovative technologies, including table-top computing environments, the integration of physical and computational components supporting new interaction techniques, the support of reflection-in-action as a problem-solving approach [Schön, 1983] and an open architecture supporting meta-design activities.

The EDC serves as an immersive social context in which a community of stakeholders can create, integrate, and disseminate information relevant to their lives and the problems they face. The exchange of information is encouraged by providing stakeholders with tools to express their own opinions, requiring an open system that evolves by accommodating new information. The information is presented and handled in a way that it can be used as boundary objects. For example, city planners contribute formal information (such as the detailed planning data found in Geographic Information Systems), whereas citizens may use less formal techniques (such as sketching) to describe a situation from their points of view. Figure 4 shows the EDC in use, illustrating the following features.

Figure 4: The Envisionment and Discovery Collaboratory (EDC)

- the pane at the bottom shows a table-top computing environment that serves as the *action space*: the stakeholders engage in determining land use patterns as a collective design activity in the context of an urban planning problem; this can be easily done e.g. by moving around tangible blocks;
- the left pane at the top is the associated *reflection space* in which quantitative data (derived dynamically from the design moves in the action space) is displayed; and
- the right pane at the top *visualizes the impact* of the height of new buildings (sketched by the stakeholders in the action space) on the environment by using Google Earth.

The EDC brings together participants from different domains who have different knowledge from various backgrounds to collaborate in resolving design problems. The contexts explored in the EDC (e.g., urban planning, emergency management, and building design) are all examples of ill-defined, open-ended design problems [Rittel & Webber, 1984].

The following example illustrates how the stakeholders gathered around the table-top computing environment explore one of these ill-defined, open-ended design problems: the community has designed a new bus route and tries to decide where the bus stops should be placed. As shown in Figure 5, stakeholders identify where they live by placing a house on the table and they indicate how far they are willing to walk in good weather (large circles around the houses) and in bad weather (small circles around the houses). After specifying this information, colored circles appear around their house icons, indicating the range of area in which they might be willing to walk to catch a bus. As the participants all specify their information, the display shows emerging, overlapping patterns of areas that might be suitable for bus stops, providing information and perspectives that no individual had in their head prior to the exercise.

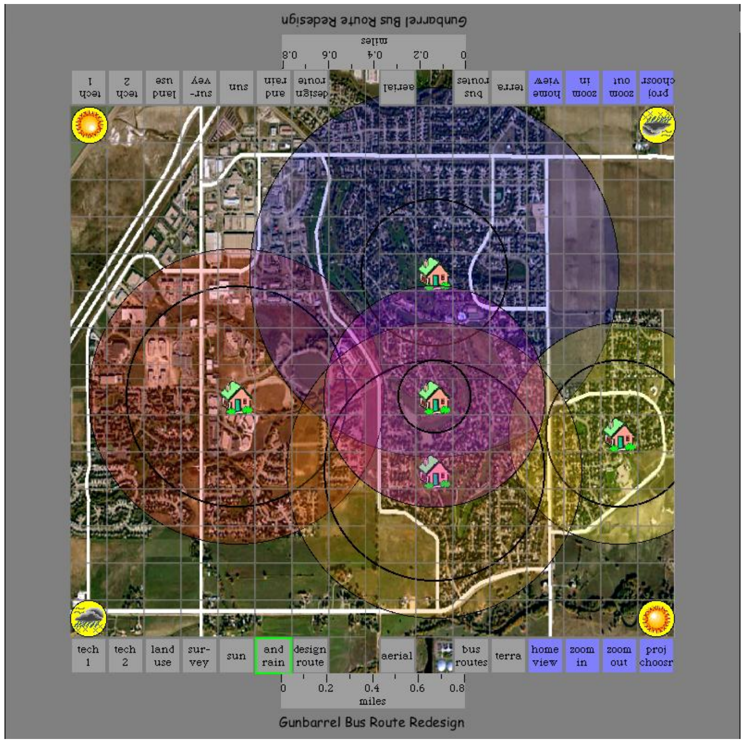

Figure 5: Walking-Distance Scenario

The EDC is a *collaboratory* [Finholt & Olson, 1997] where people come together to work on such tasks such as design, planning, developing visions, and solving concrete problems, and are willing to collaborate, to learn from each other, and to reflect and improve the tools and methods they use. The constituents of a collaboratory are not only the technical infrastructure; they also include

- people who dynamically share various roles and tasks as well as their social interaction; they are users of the collaboratory;
- places where results are documented and archived;
- properties of the collaboratory, such as subjects of reflection and making proposals for improvement; and
- some people who prepare sessions in the collaboratory and maintain it, some who have the task to develop visions of how the collaboratory can evolve, and some who work on adapting the technology and contributing to incremental improvement.

Collaboratories are places where heterogeneous perspectives are melted, transdisciplinary collaboration takes place, and learning is continuously going on [Fischer, 2001]. They are special but typical examples of STSs, and their properties and constellation are very flexible and include a wide range of possibilities for further development so that they can be considered as the typical outcome of meta-design.

5.2 *The Memory Aiding Prompting System (MAPS)*

Individuals with cognitive disabilities are often unable to live independently due to their inability to perform activities of daily living, such as cooking, housework, or shopping. By being provided with *socio-technical environments* to extend their abilities and thereby their independence, these individuals can lead lives less dependent on others.

MAPS [Carmien, 2006] provides an environment in which caregivers (such as relatives, professionals, voluntary helpers) can create scripts that can be used by people with cognitive disabilities ("clients") to support them in carrying out tasks that they would not be able to achieve by themselves.

MAPS consists of two major subsystems that present different affordances for the two sets of users: (1) the *MAPS design environment (MAPS-DE)* for caregivers, employs web-based script and template repositories that allow content to be created and shared by caregivers of different abilities and experiences; and (2) the *MAPS-Prompter (MAPS-PR)* for clients, provides external scripts that reduce the cognitive demands for the clients by changing the task. The specific tasks that we studied and supported with MAPS included: using public transportation systems [Carmien et al., 2005], folding clothes in a second hand store, and going shopping with a list of images rather than textual descriptions of objects (see Figure 6).

To effectively support users, the scripts created with MAPS-DE are specific for particular tasks, creating the requirement that the people who know about the clients and the tasks (i.e., the local caregivers rather than a technologist far removed from the action) must be able to develop scripts. Caregivers generally have no specific professional technology training nor are they interested in becoming computer programmers. This creates the need for STSs complying with meta-design guidelines (see Section 7) to allow caregivers to create, store, and share scripts. Figure 6 shows MAPS-DE for creating complex multimodal prompting sequences. The prototype allows sound, pictures, and video to be assembled by using a film-strip-based scripting metaphor.

Figure 6: The MAPS-Design-Environment (MAPS-DE) for Creating Scripts

Prompting is an established technique used for both learning and performing a task by people with cognitive disabilities by verbally instructing them through each step, until it has been internalized by the promptee, such that she could successfully perform the task unaided. Prompting has been historically part of instructional techniques for persons with cognitive disabilities:

being prompted through tasks in a rehearsal mode, and then using the memorized instructions at use time. A prompting script is a sequential set of prompts that when followed perform a task.

MAPS-PR presents to clients the multimedia scripts that support the task to be accomplished. Its function is to display the prompt and its accompanying verbal instruction. MAPS-PR has a few simple controls (see Figure 7): (1) the touch screen advances the script forward one prompt; and (2) the four hardware buttons on the bottom, which are mapped to: (i) back up one prompt, (ii) replay the verbal prompt, (iii) advance one prompt, and (iv) activate panic/help status. The mapping of the buttons to functions is configurable to account for the needs of individual users and tasks.

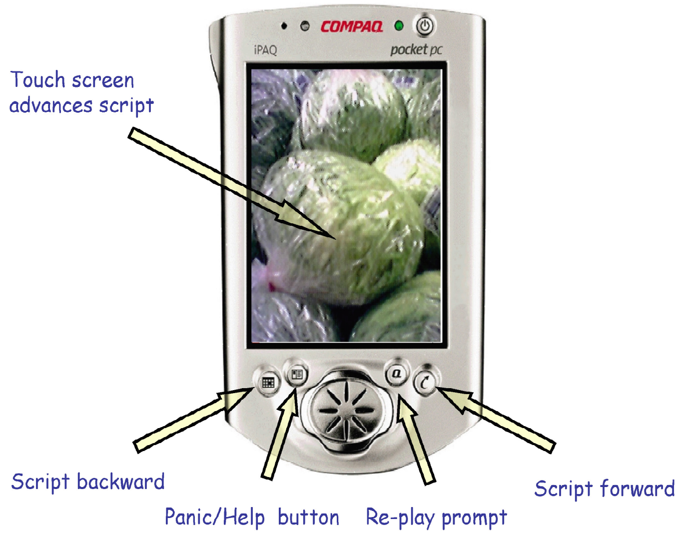

Figure 7: The MAPS Prompter (MAPS-PR) for Using Scripts

MAPS supports the offloading of the memorization and decision making elements of the task to the device and the system that supported it. Our research in this context [Carmien & Fischer, 2008] explored meta-design, cultures of participation, and underdesign by supporting mobile device customization, personalization, and configuration by caregivers and effective use by clients.

6 Findings and Assessment of the Conceptual Framework in Practice

Our conceptual framework of meta-design (Section 3) and its components (Section 4) has served as the design methodology in the development of the two case studies EDC and MAPS (Section 5). This section reports some of the findings and assessments that we have gathered by employing the EDC and MAPS in *practice* (a closely related approach linking case studies with a conceptual framework for CSCW is described in [Wulf et al., 2011]).

6.1 The Envisionment and Discovery Collaboratory (EDC)

Beyond the Information Given. One original design objective of the EDC was to create an end-user modifiable version of SimCity (http://en.wikipedia.org/wiki/SimCity_4) that transcended the modification possibility provided by the game designers (e.g.: using a bitmap editor to change the appearance of objects). A specific example that guided us in our approach: if players in SimCity notices that there is too much crime in their city they can fight crime by increasing the police force — but there is no support to reduce crime by increasing social service. The designers did not anticipate at design time that players wanted to explore this option.

While we have not directly solved this specific issue, we have included mechanisms within the EDC to allow participants to inject content into the simulations and adapt the environment to new scenarios by creating ways to link to existing data and tools so that participants can draw on information from their own areas of expertise to contribute to the emerging, shared model. These mechanisms support that the design activities complements guidelines, rules, and procedures with *exceptions, negotiations, and work-arounds* to complement and integrate accredited and expert knowledge with informal, practice-based, and situated knowledge [Orr, 1996; Suchman, 1987; Winograd & Flores, 1986].

Cultures of Participation. Urban planning (one of the major application domains for the EDC) can be undertaken as a professionally dominated activity in which experts (city planers, administrators, transportation developers) act as decision makers and citizens are consumers. The EDC involves citizens as active participants and supports a culture of participation as all stakeholders gather around a shared environment provided by a table top computing environment (see Figure 4).

Who Are Meta-Designers and What Do. They meta-designers use their own creativity to create socio-technical environments in which other people can be creative. They must create the social conditions for broad participation in design activities which is as important as creating the artifact itself. Furthermore, they encourage and facilitate the objective to develop maximum participation by activating as much knowledge as possible. The main activity of meta-designers shifts from determining the meaning, functionality, and content of a system to encouraging and supporting users to engage in these activities. Meta-designers must be willing to share control of how systems will be used, which content will be contained, and which functionality will be supported.

Support of meta-design with collaborative work practices. Early studies [Nardi, 1993] already identified that meta-design is more successful if supported by collaborative work practices rather than focusing on individuals. The studies observed the emergence of "gardeners" and "local developers" who are technically interested and sophisticated enough to perform system modifications that are needed by a community of users, but other end-users are not able or inclined to perform. The EDC supports *mutual development* [Andersen & Mørch, 2009] as a model for how professional developers and users contribute to development in both design and use. For example during the urban planning sessions, developers supported users in overcoming problems with the technical environment; in doing so, they interacted with users and became immediately aware of further needs for technical improvements.

Meta-design promotes the quality that the set and the characteristics of the involved roles are highly dynamic: new roles emerge such as power users or co-developers [Nardi, 1993], and the traditional roles can continuously achieve and lose competencies that are needed to contribute to the development of their tools. Meta-design promotes a rich *ecology of participation* [Fischer et al., 2008; Preece & Shneiderman, 2009], which includes a broad variety of roles with varying characteristics.

Technical Infrastructures and Social Interactions of Various Roles Are Intertwined. An early technical realization of the EDC required that the participants take turns (e.g.: in the scenario represented by Figure 5). Consequently, participants had to wait until one person has completed the moving around of a toy block before they could go ahead with their own contributions. Experimental design sessions clearly indicated that this was a restriction at odds with the social interactions that the participants preferred. A newer hardware environment eliminated this limitation and supported more flexible and fluent interactions. However, it has to be considered whether the possibility to act simultaneously might reduce the awareness of what others are doing. Design trade-offs of this kind provide further evidence for the reciprocal shaping between technical features and social interactions.

Collaboratories Evolve in Cultures of Participation with a Variety of Participants in Various Roles. The EDC environment (similarly to other cultures of participation such as open source systems [Fischer et al., 2008]) supports a rich ecology of roles and the migration between them. The particular roles that emerged in the EDC environment are:

- *project leaders*, who are responsible for the overall design and the usage of the collaboratory;
- *chief designers*, who acted as meta-designers;
- *users* (being knowledgeable in different domains), who owned (e.g.: being residents in neighborhoods) parts of the problem to be investigated (e.g.: the design of a new bus line and where the bus stops should be placed);
- *scientists*, who use the collaboratory as members of research teams; and
- *students and teachers*, who use the collaboratory for learning and knowledge construction.

In traditional design environments, it would have been a goal that the competencies and roles of the involved stakeholders are clearly defined and the responsibility and authority of individuals are visible for all participants. By contrast, in an evolving culture of participation, the tasks, activities, and competences of these roles can overlap: the technical infrastructure can be considered as a domain itself, and problems of this domain are discussed and partially solved by everybody in the collaboratories; the experts of other domains e.g. urban planners) can contribute with proposals for technical improvement (e.g. color-coding various risk-zones with respect to flooding); thus, users become co-developers and vice versa, developers become co-users (by contributing data which supports urban planning).

Adaptation of the Technical Infrastructure Is User-Driven. In his book "Democratizing Innovation" [von Hippel, 2005], the author provides evidence for the following claim (page 1): *"Users that innovate can develop exactly what they want, rather than relying on manufacturers to act as their (often very imperfect) agents. Moreover, individual users do not have to develop everything they need on their own: they can benefit from innovations developed and freely shared by others".* Interesting evidence is provided from a variety of different areas: new mountain bikes, new surf boards, and new application software is envisioned and *designed primarily by lead users rather than by manufacturers*. We observed the same developments in the EDC: innovative ideas for new developments originated with the needs of users. Some prominent examples of design requirements originated from users are: (1) the need for a virtual EDC (possibly implemented in an environment such as Second Life) to support the collaboration of design teams in Boulder and in San Jose, Costa Rica; (2) the integration of the EDC with geographical information systems to greatly reduce the overhead to apply urban planning situations to different locations; and (3) the linkage with Google Earth to easily create visualizations of new buildings from different perspectives.

In the course of this collaboration, not only the technical infrastructure was adapted but also the social system. Newcomers brought in new perspectives and ideas of how the EDC could be enhanced and used. From the perspective of meta-design, collaboratories are self-referential socio-technical systems: they are designed to evolve, they are the place where this evolution takes place, they provide the infrastructure that supports this evolution, and they provide the context that represents the common ground on which this evolution is driven by the communication between problem owners.

6.2 *The Memory Aiding Prompting System (MAPS)*

Caregivers as end-user designers. A unique challenge of meta-design in the domain of cognitive disabilities is that the clients themselves cannot act as designers, but the caregivers must accept this role. Caregivers, who have the most intimate knowledge of the client, need to become the end-user designers. They mediate between the contribution of MAPS-designers (the meta-designers) and the needs of clients by developing situationally adapted scripts (see Figure 8).

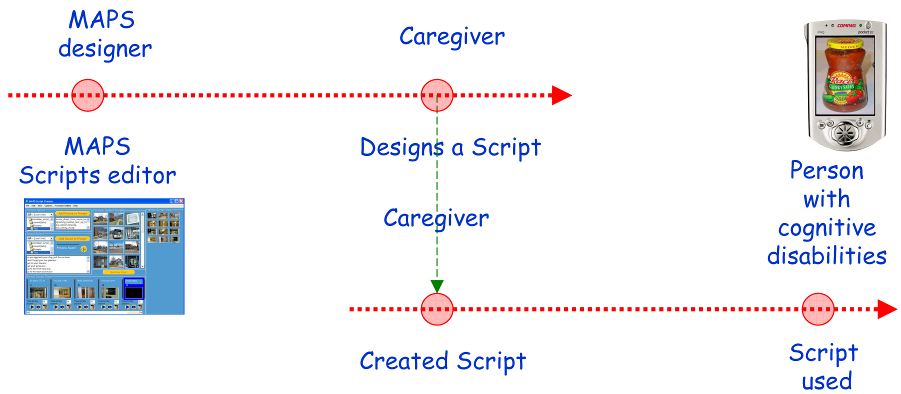

Figure 8: Empowering Caregivers to Act as User-Designers

Caregivers generally have no specific professional technology training nor are they interested in becoming computer programmers. This creates the need that meta-design provides extensive end-user support to allow caregivers to create, store, and share scripts. To identify requirements for meta-design, the following studies were conducted:

- discovering and learning about the client's and caregiver's world and their interactions;
- observing and analyzing how tasks and learning of tasks were currently conducted;
- understanding and explicating the process of creating and updating scripts;
- comprehending and analyzing the process of using the scripts with a real task; and
- gaining an understanding of the role of meta-design in the dynamics of MAPS adoption and use.

Underdesign: An Approach Coping with the "*Universe of One*" Problem. People with cognitive disabilities represent a *"universe of one"*: a solution for one person will rarely work for another. The "*universe of one*" conceptualization is based on the empirical finding that (1) *unexpected islands of abilities* exist: clients can have unexpected skills and abilities that can be leveraged to ensure a better possibility of task accomplishment; and (2) *unexpected deficits of abilities* exist. Accessing and addressing these unexpected variations in skills and needs, requires an intimate knowledge of the client that *only caregivers* can provide. The scripts needed to effectively support users are specific for particular tasks and contexts, implying the requirement that the people who know about the clients and their needs (i.e., the local caregivers rather than a technologist far removed from the action) must be able to develop scripts. The meta-design environment (developed in this case by us) needs to be underdesigned (we being the technologists far removed from the action) allowing the caregivers as user-designers to create the situationally informed specific developments in accordance with the clients' varying needs, and to implement them in dynamically changing social contexts.

Currently, a substantial portion of all assistive technology is abandoned after initial purchase and use resulting in that the very population that could most benefit from technology is paying for expensive devices that end up in the back of closets after a short time.

By designing MAPS as a meta-design environment, caregivers were able to create an environment that matched the unique needs of an individual with cognitive disabilities [Carmien & Fischer, 2008]. MAPS represents an example for democratizing design by supporting meta-design, embedding new technologies into socio-technical environments, and helping people with cognitive disabilities and their caregivers have more interesting and more rewarding lives by empowering caregivers to provide a situated and tailored STS the needs of the persons with cognitive disabilities thereby allowing them to do things that they could not have done with the empowerment provided by MAPS .

Design over Time: Instantiating the SER Model. The design of MAPS was grounded in the conceptual framework of meta-design and contributed to its extension. The theme of design over time was illustrated in both MAPS-DE with the addition of a multi-script modality and in MAPS-PR with the reuse of script sequences. By designing the MAPS environment to enable script redesign and re-use, caregivers were able to create precisely fitting solutions for the user with cognitive disabilities. MAPS represents an important example for democratizing design by supporting meta-design, embedding new technologies into socio-technical environments, and helping people with cognitive disabilities and their caregivers have more interesting and more rewarding interactions.

6.3 Potential Drawbacks of Meta-Design

It has to be clearly stated that the goal of meta-design is not to let people with little or no experience develop and evolve sophisticated software systems, but to put *owners of problems* in charge. Meta-design does not eliminate expertise, but recognizes the multi-faceted aspects of expertise (e.g.: in architecture, inhabitants should be free to arrange their office furniture but they should not be able to move the structure-bearing wall between their and their neighbors' offices).

The Tension between Standardization and Improvisation. Meta-design creates inherent tensions, for example, between standardization and improvisation. The SAP Info (July 2003, page 33) argues to reduce the number of customer modifications ([Fischer & Giaccardi, 2006], p.446): *"every customer modification implies costs because it has to be maintained by the customer. Each time a support package is imported there is a risk that the customer modification may have to be adjusted or re-implemented. To reduce the costs of such on-going maintenance of customer-specific changes, one of the key targets during an upgrade should be to return to the SAP standard wherever this is possible."* Finding the right balance between *standardization* (which can suppress innovation and creativity) and *improvisation* (which can lead to a Babel of different and incompatible versions) has been noted as a challenge in open-source environments, in which forking has often led developers in different directions.

Participation Overload. Meta-design (and specifically the required active engagement in cultures of participation) open up unique new opportunities for mass collaboration and social production [Benkler, 2006], but they are not without drawbacks. One such drawback is that humans may be forced to cope with the burden of being active contributors in *personally irrelevant activities* leading to a *participation overload*. "Do-it-yourself" societies empower humans with powerful tools, however they force them to perform many tasks themselves that were done previously by skilled domain workers serving as agents and intermediaries. Although this shift provides power, freedom, and control to customers, it also has urged people to act as contributors in contexts for which they lack the experience that professionals have at their disposal [Hess et al., 2013].

More experience and assessment is required to determine the design trade-offs for specific contexts and application domains in which the *advantages* of cultures of participation (such as extensive coverage of information, creation of large numbers of artifacts, creative chaos by making all voices heard, reduced authority of expert opinions, and shared experience of social creativity) will outweigh the *disadvantages* (accumulation of irrelevant information, wasting human resources in large information spaces, and lack of coherent voices). The following research questions need to be further explored [Fischer, 2011]:

- If more and more people can contribute, how do we assess the *quality and reliability* of the resulting artifacts? How can curator networks effectively increase the quality and reliability?

- What is the role of trust, empathy, altruism, and reciprocity in such an environment and how will these factors affect cultures of participation?

7 Guidelines for the Meta-Design of STSs

This section describes *guidelines* [Fischer et al., 2009] derived from our conceptual considerations (see the sections on meta-design and practical experiences) with the development of STSs.

Construction Kits. From a technical point of view, a meta-design framework should include components and building blocks for the creation of content and modifications of the system. The users-as-designers of a STS should be empowered to combine, customize, and improve these components with a reasonable effort or ask power users or local developers to do so [Nardi, 1993]. The building blocks will have the role of a seed that inspire the evolutionary growth of a new assembly of components that fits into the STS. Meta-design must be continuously aware of new technological trends, and the meta-designed framework must be flexible enough to integrate these trends by providing new building blocks.

Underdesign for Emergent Behavior. STSs need to be *underdesigned* so that they can be viewed as *continuous beta* that are open to facilitate and incorporate emergent design behavior during use. Underdesign is not less design but different design: it allows all stakeholders with various and varying competences to collaboratively design socio-technical solutions. Underdesign explores the most promising ground between: (1) providing a powerful seed without re-inventing the wheel or violating constraints such as legal norms, ethical restrictions, and the like; and (2) allowing the users-as-designers to transcend the information given and functionality provided. It shares many objectives with *liberterian paternalism* [Thaler & Sunstein, 2009]: the paternalism part being grounded in the objective that it is important, legitimate, and supportive that meta-designers (called “choice architects” in the “Nudge” book) provide seeds and support environments for users and the liberterian part allowing users to be free to do what they like and create the functionality that they need.

Foster and Support Cultures of Participation. People should be enabled and attracted to bring their competences and perspectives into the development of STSs requiring transparent policies and procedures to incorporate user contributions. To motivate more users to become developers, meta-design must offer “gentle slopes” of progressive difficulty and incremental extension of the included design aspects so that newcomers can start to participate peripherally and move on gradually to take charge of more difficult tasks [Fischer et al., 2008]. Rewarding and recognizing contributions is an essential prerequisite of fostering intrinsic motivation. Roles and their rights and duties must not be fixed for the period of an STS’s evolution but should be part of this evolution so that domain experts can become co-designers, new roles can be integrated and control can be shifted in accordance with increased competencies [Preece & Shneiderman, 2009].

Additional Discourses. While meta-design changes design activities from developers and users, it has a fundamental impact on the following aspects of human behavior [Benkler & Nissenbaum, 2006]:

- *Motivation*: Human beings are diversely motivated beings acting not only for material gain, but for psychological well-being, social integration, connectedness, social capital, recognition, and for improving their standing in a reputation economy. The motivation for going the extra step to engage in cultures of participation is based on the overwhelming evidence of the IKEA effect [Ariely, 2010] that people are more likely to like a solution if they have been involved in its generation; even though it might not make sense otherwise. Creating something personal (such as hand-knitted sweaters and socks, home-cooked meals) even of moderate quality, has a different kind of appeal than consuming something of possible higher quality made by others.
- *Control*: Meta-design supports users as active contributors who can transcend the functionality and content of existing technical systems. By facilitating these possibili-

ties, control is distributed among all stakeholders in the design process. Meta-design erodes monopoly positions held by professions, educational institutions, experts, and high-tech scribes [Fischer, 2002]. Empirical evidence gathered in the context of the different design activities [Ariely, 2010] indicates that projects are less successful when users are brought into the process late (thereby denying them ownership) and when they are "misused" to fix problems and to address weaknesses of systems that the developers did not fix themselves.

- *Changing Human Behavior*: Technology alone does not determine social structure nor does it change human behavior: it creates feasibility spaces for new social practices [Benkler, 2006] and it can persuade and motivate changes at the individual, group, and community level. Meta-design can change people's lives (1) by making it easier for people to do things, (2) by allowing people to explore cause-and-effect relationships, and (3) by providing value that cannot be accounted for in monetary terms. Research in behavioral psychology [Thaler & Sunstein, 2009] has shown that providing feedback, goal setting, and tailored information are useful in motivating people to change their behavior.

Promote Mutual Learning and Support of Knowledge Exchange. Users have different and varying levels of skill and knowledge about systems. To get involved in contributing to the system's evolution or using the system, they need to learn many things. Peer users are important learning resources. A meta-designed STSs should be flexible enough to address the skill differences and support knowledge sharing mechanisms that encourage users to learn from each other. Knowledge management infrastructures should be integrated into STSs as important components that support their evolution.

8 Summary

New media and new technology provide new possibilities to rethink learning, working, and collaborating. In this article, we argued that new media and new technology on their own cannot support and transform these activities to meet the demands of the future, but that they have to be integrated into STSs.

Our research is anchored in the basic assumption that STSs cannot be designed anticipating all future demands and uses and that meta-design supporting users as designers is not a luxury, but a necessity to address the challenge of dynamically changing needs and conditions. We discussed meta-design as a conceptual framework which complements other more established approaches and we described essential components of this framework: cultures of participation; seeding, evolutionary growth and re-seeding; and underdesign. Two case studies of specific STSs illustrated how meta-design has served as the foundation of these development efforts and we discussed some of the findings derived from our assessments about the conceptual framework.

Socio-technical phenomena are self-referential: on the one hand, they are the outcome of design and evolution, and on the other hand, they have the potential to support their own evolution. The strengths of STSs result from the integration of deterministic structures and processes and the contingency of social systems. Meta-design supports this integration.

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- Google research award *"Motivating and Empowering Users to Become Active Contributors: Supporting the Learning of High-Functionality Environments"*; and
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