Shaping Intelligent Environments: the Sign of Design

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ABSTRACT
The paper provides a vision of future intelligent environments from a design perspective. Existing ideas about ubiquitous computing and related research methods are considered. I discuss the expressive potential of design in shaping meaningful relationships between users and environments, and the challenges to effectively involve designers in the HCI research community.

Categories and Subject Descriptors
H 5.2 [**User Interfaces**]: theory and methods, user centered design.

General Terms
Design, Theory.

Keywords
Design, intelligent environments, artifacts, ubiquitous computing.

1. INTRODUCTION
Along with the pervasive introduction of Information Technology (IT) into our everyday life, HCI research has shown the need for novel multidisciplinary approaches, and for more holistic considerations about users' experiences with IT artifacts. The emergence of graphical user interfaces in a first stage [42], and the embodiment of interaction and computing within our physical and social contexts later on [9], has required new approaches towards interaction design.

The relationship between HCI and design has been shaped and discussed in different contexts. The involvement of design thinking in the HCI community has been claimed and fostered in publications and conferences, but design professionals, educated in such discipline and practice, are still rare in the community and face challenges in entering the research domain [4][42].

The relationship between design and HCI is considered in this paper. I propose a design perspective to look at some of the assumptions that characterize the vision of ubiquitous computing and intelligent environments in the HCI research field. My argument supports the importance of creating artifacts that have a meaningful role in the social psychology of objects and technology. From this perspective the involvement of design competencies becomes beneficial to the creation of future intelligent environments and in this sense I discuss the scientific contribution of the design discipline to the HCI research field.

2. DESIGN AND HCI
The relationship between design and HCI can be better explained if we distinguish between *discipline* and *field of research*. The ACM Curricula for Human-Computer Interaction [1] defines HCI in the large as an interdisciplinary field of research, emerging as a specialty concern within several disciplines, each with different emphases. The field arose from the evolution of the relationship between computer sciences and behavioral sciences. Along with the distribution of IT in everyday life activities, targeting different user groups, HCI has reached out to other disciplines, such as sociology, anthropology, as well as design. According to Fallman [10], "HCI tends to involve academic researcher in design, as well as involving the designer from industry in HCI research."

In this sense two approaches can be distinguished. The first one strives for the education of design thinking in HCI (i.e., *design-oriented research* [10]). Such an approach has been discussed in literature [40] as well as conferences [34][43]. This has motivated the creation of new multidisciplinary educational programs in HCI, for example at Stanford [41], Carnegie Mellow [5], Georgia Tech [15], and Cornell University [6]. Most of these programs are tightly coupled with the departments of computer science and psychology. Some of the main reasons that justify this approach can be found in [35] and are partly due to the generative aspect of design, in contrast to the predictive one of computer and behavioral sciences. An excessive focus of HCI on evaluation rather than on production raises the concern of hindering the creation of IT artifacts with a value for the industry and for the market [35][3], thus eventually hampering the impact of HCI. Furthermore, the education of design thinking to HCI professionals is expected to facilitate the communication between researchers and practitioners.

The second approach brings HCI to the design discipline. This approach has influenced the programs of educational centers for design such as the Design Department of the TU/Eindhoven [37], the Royal College of Art [19] and the Domus Academy of Milan [7]. According to Fallman, this approach leads to *research-oriented design*: "research oriented design naturally has problem solving within a given paradigm as its main component, as problem setting may become practically infeasible in the commercial world for which the product is primarily tailored. It may relate to research, but it has the production of new artifacts as its main motivation, not the production of new knowledge" [10]. This view of the relationship between the design discipline and the HCI field implies the risk of excluding designers from the HCI area of research. In other words, it risks excluding the design discipline from the design research. This aspect is further discussed in the following section.

2.1 Design and Research
Design curricula in higher education rarely include design research as a set of skills with extremely high strategic values [21]. As observed by Hevner et al. [18] what differentiates routine design, or system building, from design research, is that the first applies already defined artifacts of knowledge to well defined and known problems (i.e., problem solving), while design research addresses unsolved problems and produces a contribution to the

archival knowledge base of foundations and methodologies (thus implying problem setting).

Design research is therefore creating artifacts which can establish a communication among design stakeholders, in iterative phases of problem setting and problem solving. Furthermore it promises to contribute to the identification of users' benefits and identification of requirements in HCI. In this sense the education of design processes and techniques in faculties of computer sciences, psychology and information sciences enhances the establishment of a communication language. But what is the potential of the design discipline, which is taught at design faculties, within the field of design research?

In the body of publications within the HCI field, several ones discuss design issues, but very few ones are authored by designers [4][42]. In order to appreciate the potential contribution of the design discipline to the field of HCI it is appropriate to identify the main aspects that distinguish design from other disciplines.

Sketching has been recognized as the archetypal design activity, characterizing designers' way of thinking [2][3][10][13]. Sketching is especially essential to designers for problem setting, as well as communication. On top of that I think there is another factor dealing with communication that differentiates design from other disciplines. Designers "create to communicate", while other disciplines "communicate to create". The difference is less trivial then it might seem. Designers are trained to sketch, shape, model and present in order to externalize and communicate a concept, i.e. a message. It is a message to themselves in a first stage, i.e., sketching for reflection, and to others later on, for communication. As in Simon [36] design is a science of the artificial, based on making. It contributes to a body of knowledge about artificial objects and phenomena designed to meet certain desired goals. Shaping and making a concept evident (i.e., representing a message, a vision) is essential to designers for introspective as well as for interpersonal communication. Other disciplines are more familiar with articulating knowledge in an explicit form, so as to provide guidelines to design and creation. As in [18] behavioral and natural sciences inform researchers and practitioners through the development and justification of theories explaining or predicting phenomena related to human and organizational interaction with information systems.

Designers' focus on creation and representation are some of the reasons why designers are more familiar with portfolios rather than with publications. Recognizing the difference and potential of designers' perspectives within HCI field of research is a first step towards the involvement of designers in shaping future technology and environments. In the following section a design perspective is described: from this perspective I look at some of the ideas concerning ubiquitous computing within the HCI community. The designer's needs of creation and evident representation for communicating inevitably affect the point of view from which those ideas (e.g. invisibility, cfr. section 5) are considered.

3. AN EVOLUTIONARY PERSPECTIVE

Design changes by definition the state of the world through the introduction of novel artifacts entering our environments. We can intend artifacts as objects created by human craft, which are not given in nature.

If we think about the world as an information display [38] we can realize the survival value of the evolution of our perceptual system. Our capability of distinguishing textures, shapes, patterns, thanks to our networked senses, enables us to make sense of the world and to interact with it. In the human evolution history it has enabled navigation, food seeking and use of tools. To this respect Gibson's concept of affordances [16] refers to aspects of an object which suggest how the object should be used; a visual clue to its function and use. Affordances are therefore essential for understanding the potential of interaction and manipulation in the environment.

Along with the evolution of perception, i.e., evolution of understanding and interacting, we have evolved our ways to shape artifacts and, more in general, environments, so as to communicate their potential for interaction. In other words, we have evolved our design skills. From this perspective, design plays the role of a language enabling communication between humans and humans and between humans and the world.

De Souza's [7] definition of HCI artifacts helps in identifying the semiotic, communicative nature of the relationship between designers, artifacts and users, also supported by Norman [25]. In her words, "HCI artifacts are intellectual constructs that, as all intellectual products, are communicated as signs, in a particular kind of discourse that we need to interpret, learn, use, and adapt to various contexts of need and opportunity".

If we conceive design as an evolving language, this implies:

- communication of a message;
- understanding of the audience;
- confidence with grammar, logic, vocabulary, expressions;
- adaptation to the context, e.g. to the media.

In this sense design is instrumental to augment people's understanding of the environment and their capability to interact with it: that is, to make people more intelligent and creative. Artifacts then are media conveying such communication between humans and humans, and between humans and environments.

The hybrid nature (i.e., physical and digital) of IT artifacts makes technology instrumented environments more dynamic and interactive. Users' control and interaction possibilities increase, thanks to the digital nature of information (e.g. e-mail, digital photography, sms). This allows new forms of communication and behaviors: in this vision, when users take hold of the technology, they speed up and affect the evolution of the design of IT artifacts and environments.

4. THE INTELLIGENCE IN THE ENVIRONMENT

When talking about intelligent environments, smart environments, context-aware environments, usually the assumption is that a technological system is somehow able to make inferences about the context, based on some sensed data, and to react accordingly. Much work has been done in order to model the context so as to make the system aware of it by connecting sensors that measure users, environment, and domain parameters (e.g. body temperature, proximity, acceleration). The intelligence is therefore mostly referred to the system capability to reduce and interpret complexity, and to adapt to the context.

Controversially to such system perspective, it remains a matter of research how to enhance humans' awareness of their interactive context, encompassing digital and physical artifacts. And, more important, how to support people's *reflection* on the environment: reflection is something that an *action-reaction* system is not capable of.

From an evolutionary perspective of the environment, an intelligent environment is one that optimizes people's efficiency of perception: i.e., it enables people's awareness and sense-making of the context, with minimum effort and maximum benefit.

Such a principle is in line with the foraging theory of information [30], which conceives people as information rate maximizers of benefits/costs. As in Miller [23], humans are information seekers as food seekers, or informavores: organisms that hunger for information about the world and themselves. Humans seek, gather, share, and consume information in order to adapt, therefore in order to evolve. To support people's informed interactions, designers need to create information scent [31]: "proximal cues perceived by the user that indicate the value, cost of access, and location of distal information content".

Such theories are mostly referred to the field of information visualization. Their evolutionary and economic meaning, though, is significant in the perception of information in general. In this sense I see the mission of design as support to humans' reflection, i.e., humans' intelligence: this aspect also distinguishes human beings from other species, who are only capable of action and reaction.

People are inclined to engage and invest cognitive effort when the perceived benefit is convenient for their personal economic system. Thus designers need to:

- identify and maximize users' benefit (i.e., identify and meet users' needs, attitudes, values); and to
- minimize users' effort (i.e., represent information in an expressive, meaningful way).

In instrumented and highly interactive environments visual representation might not be always necessary or appropriate. Still, users need to be aware whether and where virtual information is present in the real environment and how virtual information is structured: what communicates with what, interaction regions and the relationship to the user's context.

In the physical experience we explore the outside world with our senses: this is the major source for the creation of users' mental models of how things work. The main account of sensory motor theory [28] of perception is that perception does not happen in the brain, seen as black box, but rather it is something humans do as explorative activity. This research promises to offer innovative ways to deliver awareness of the interactive context to the user, without affecting her focus of attention. Furthermore, the so-called *smart materials* (i.e., materials that respond with a change in shape upon application of externally applied driving forces) provide interaction designers with novel possibilities for representing the internal state of the interactive products [32].

5. THE MYTH OF INVISIBILITY

One idea that accompanies the vision of ubiquitous computing is invisibility. As in Weiser and Brown [39]: "the most profound technologies are those that disappear". The focus of attention will shift from the tool to the task, so that the tool will become invisible.

When such statement is literally interpreted, futuristic scenarios emerge in which the physicality of the artifacts will reduce dramatically: we will interact with information without input devices, but rather with multimodal interfaces, possibly based on gestures and speech.

Taking for granted such a kind of "minimal design" of future environments has certain implications. First, it bears the risk of loosing a sense of reference: in order to provide users with awareness of the interactive context it is important that they have a reference system, which is personal and sharable at the same time. In other words, affordances for interaction need to be perceptible.

Secondly, we risk missing the chance of giving technological digital artifacts a proper role in the social psychology of objects, i.e., how people communicate through artifacts with each-other [24], and how artifacts become an expression of individuals' personality [17].

Our physical analogue tools are not invisible. We have evolved ways to manipulate them through the human history, and this has helped in shaping the tools to better accommodate our manipulation needs. The way our analogue tools have evolved did not make them disappear. On the contrary, especially those objects that populate our everyday environments have differentiated and acquired a semantic value to accommodate personal preferences. And, most important in this context, they have a role in the social psychology of objects.

To better explain this concept, take a fork for a starter, in a luxury restaurant, for example (Figure1, left). Its shape serves the functional need of grabbing food, as well as the manipulation need of being handled with one hand. Additionally, its material and shape have a semantic meaning: they can reflect an historical époque, a culture, a social status, basically the object represents a material culture.

Here intelligence can be distinguished in different aspects. First, someone designed such a tool to communicate a certain message or value, both functional (how to handle such a tool) and symbolic (a social status, or its appropriateness for a certain course, conveyed by its small size). On the other hand, a user is adopting the tool both for functional purposes (bring food to the mouth) as well as symbolic ones (adhere to a social context). Furthermore, the placement of the starter fork next to the bigger fork for the main course belongs to a cultural ritual and convention: if the same fork were rolled in a paper napkin and put in a cup together with other cutlery on a table without cloth, this would send to the world a complete different message about the restaurant where we are.

What does this mean in this discussion? A fork is a tool that like many others in our environments has the potential of creating a meaningful relationship between people and people, and between people and the environment. If we expect digital technology to enter our everyday life environments we need to consider the social psychology of IT artifacts and make people able to interact with them, both functionally as well as symbolically. For this reason the assumption of invisible embedded technology bears the

risk of hindering a meaningful dialogue between people and artifacts and between people through artifacts.

5.1 "Talking" artifacts

As in Norman [26], the studies conducted in the Psychology Department at Northwestern University [27] demonstrate that we have three levels of processing information, depending on three different levels of the brain: the visceral level, dealing with instinct, the behavioral level, dealing with behavior and use, and the reflective level, dealing with contemplation. These different levels ask for different kinds of design. The design of IT artifacts has been mostly addressing the behavioral level of perception, but experiences encompass all of them.

Designers have been trained in analyzing and creating semantic relationships between humans and artifacts and the experience that results. In 1958, the Italian designer Bruno Munari explored the anthropomorphic qualities of the fork, seen as an extension of the hand (Figure 1, right). His work "Forchette Parlanti" ("Talking Forks") does not fulfill functional needs; rather it exploits the fork artifact as media to trigger the re-thinking of everyday life tools and their shapes. Therefore he addresses the reflective level of perception. In this sense "talking forks" refers to the expressive potential of the artifact and suits as exemplification in our discussion on communication.

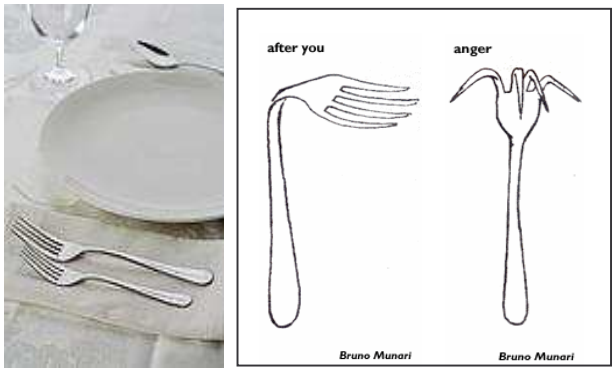

Figure 1. Left: Forks on a set table, source http://corbis.com. Right: Bruno Munari's illustrations of "Forchette Parlanti", source http://www.dolcevita.com/design/posate/muna.htm

6. WIRELESS AND WIREFUL

The idea of invisibility is reinforced by the growing possibility to establish wireless communication among devices, thus reducing the need of explicit wire-based connection. On the other hand, in parallel to the increasing number of devices inhabiting our environments, it increases the need of power supply, thus requiring an increasing number of cables. Especially in domestic environments, people tend to reduce the visibility of cables, both for aesthetic as well as for safety reasons. For new technology artifacts to be accepted within the domestic walls their physical appearance needs to be integrated in an unobtrusive way. This factor calls for novel design solutions balancing the trade-off between functionality and aesthetics. This doesn't necessarily mean that cables must be hidden. In Figure 2 and 3 some examples are illustrated. The Wiresnakes (Figure 2, designed by Jeff Shore), CableTurtle and MrTwister (Figure 3, both designed by FLEX/the INNOVATIONLAB design studio) address the issue of managing redundant length of cables in a ludic way, reinterpreting artifacts that are usually kept in "back regions" [17] of our environments.

Figure 2: Wiresnakes, source: http://www.momastore.org

Figure 3: Left: CableTurtle. Right: MisterTwister. Source: http://www.flex.nl

Furthermore, wireless technology and miniaturization of components justify the fact that people own an increasing number and variety of personal portable devices. This suggests the need to design new, portable accessories. This is one field where design can express functional and symbolic purposes, creating a certain experience across the physical and digital nature of the artifact.

"For a fun and practical way to protect your iPod, dress it up in these iPod Socks" is the Apple advertising quote for the IPOD colorful case (Figure 4, left). "Arm yourself with the ultimate workout companion: iPod nano Armbands" is the one for the armband accessory (Figure 4, right). The design of the artifacts and of their communication clearly encourages the user to establish an affective and playful relationship with the products. In this case the added value that designers want to express and communicate to users' economic system (cfr. Section 4) is more symbolic then functional.

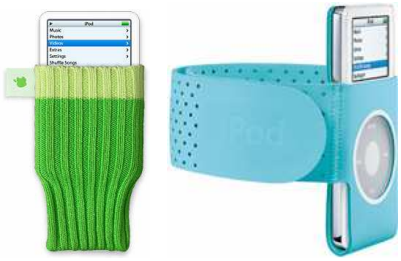

Figure 4: Left: iPOD sock. Right: Armband for iPod nano Source: http://www.apple.com/ipod/accessories.html

7. STAGE AND BACKSTAGE

Another assumption often related to the vision of instrumented environments is that technology is in the backstage. Sensors, projectors, cameras are invisibly embedded in the physical environment. Instrumented environments of research labs like the Aware Home at the Georgia Institute of Technology [13], the Homelab at Philips Research [29], and the Place Lab/House_n at the Massachusetts Institute of Technology [22] have built ad-hoc observation rooms where researchers can invisibly analyze sensed data and observe users' behaviors as they engage with technologically enhanced spaces. The idea is to make these

environments as close as possible to normal domestic ones: users are invited to inhabit them for a certain time, and to normally act as they would be in their homes. But *acting*, as if they were on a stage, aware of the hidden cameras, is exactly what they are doing. Ad-hoc built instrumented environments can hardly provide the familiarity and naturalness with which people interact with their own homes, even when technology is in the backstage.

The vision of technology in the background can imply the assumption that the domestic infrastructure of the future will be completely revolutionized to host new sensors networks enabling context-adaptive appliances. This vision might get true on a long term, but it seems more realistic that modular appliances will progressively enter our existing houses; thus, they will need to integrate and communicate with our existing set of artifacts. In this sense the design of IT artifacts that can be tested or, staying with the communication metaphor, "discussed" in already existing environments, can be beneficial in the way that users don't need to familiarize with the environment.

Other approaches make use of semi-finished artifacts, such as sketches, scenarios, prototypes, to study people's attitudes towards the introduction of technology into their everyday life environments. These artifacts become means of communication between designers, stakeholder, ethnographers and users: users are then invested as design partners, and are involved in the design process.

In this participatory design approach it is important for designers to find the right balance between finished and unfinished solutions to present. The more the idea is specified and refined, the less room for expressing personal creativity is left to stakeholders and users. On the other hand, the more abstract is the idea, the harder is users' imagination task. But when we make explicit the role of users as co-designers, technology in the foreground might be not simply accepted, but even beneficial for creativity and communication.

Cultural and technology probes [11][19] are meant to stimulate such communication. Rather then semi-finished artifacts, in this case it is more appropriate to talk about "open" artifacts: they are designed as provocation to explore users' subjective experiences with the artifact. Design for interpretation is the focus of [33]. In this work artifacts are intentionally open for users' interpretation and serve to unfold the negotiation between users, designers, researchers and other stakeholders. This kind of artifacts is not meant to the direct elicitation of users' needs, nor to the definition of users' requirements. Rather, it can trigger unexpected users' experiences and reactions, thus stimulating designers' reflection and creativity [12].

8. ACTORS AND DIRECTORS

As discussed in the previous section, observing users "behind a wall" might not be the only way to gain knowledge about people's attitudes and needs. Especially, considering that IT artifacts have enabled users to master their communication in novel, proactive ways. Digital photography, for example, along with broadband availability, has created new possibilities for sharing pictures, thus affecting picture-based interpersonal communication. This has lead to a sort of democratization of photography: more people can more easily and economically capture, edit, duplicate, share and store pictures. The enhancement and economic improvement of such processes does not conflict with the value of accomplishment: users still feel challenged in taking the right shot, and have learned to master software for color editing and archiving. Providing a sense of accomplishment and mastery is vital in order to preserve engagement, self-expression and stimulate human creativity.

As Shneiderman observes [35], "the old computing is about what computers can do; the new computing is about what people can do": from this perspective, computers are not meant to replace or mimic human abilities, but rather to augment them and help them in achieving novel, creative, better performances. In the next paragraph the Living Cookbook project is illustrated as example to this respect.

8.1 The Living Cookbook

The Living Cookbook is a domestic appliance we have designed and developed in our lab. It explores cooking as social experience: the goal is to exploit technology in order to enhance people communication, creativity and collaboration around the cooking activity.

The application consists of a camera, a tablet PC mounted on a kitchen cupboard and a projector connected to a server (Figure 5, left). On the tablet PC a digital cookbook is displayed and interactable (Figure 5, right). On the same interface people can either author a new recipe in their personal book, or consult the book and learn someone else's recipe. In the authoring/teaching mode, the video of the cooking session is captured by the camera: in the learning mode the video is projected on the wall and the learner can cook along.

The conceptual model of this device is the one of a tape recorder, which has two primary functionalities, record and playback, as well as the secondary functions of fast forward, backward and pause. The idea is to make people's cooking experiences recordable and shareable, so as to maintain cultural and social roots on the one hand, and stimulate cultural and generational fertilization on the other.

Traditional paper cookbooks can't be personalized and can hardly trigger an affective link to the dishes they present. Instead of simply exchanging written instructions, we capture the whole cooking process with annotated audio and video and make it available for others. The emotional quality of content created by family members or intimate friends is very different in comparison to the cooking sessions broadcasted on TV shows for a large audience: people can personalize their experience and as a consequence their communication.

When users give instructions for a recipe, they perform their cooking session. We therefore rely on people's interest in communication and story telling, as they are turned into actors of a participatory theater, who interact with their audience via technology.

The application has been iteratively tested by "cooks" internal and external to the research team and each test has lead to a discussion during a meal. Although the development is still in progress, the artifact has supported our research in raising discussions among us and with users about the experience that such an application can deliver. In this sense it has contributed to gain an insight on the potential of IT artifacts to beneficially augment creativity of everyday life activities.

Figure 5: Left: a camera is placed on the wall in the left up corner and a tablet PC is mounted on the kitchen cabinet. Right: a user interacting with the Living Cookbook.

9. TOWARDS DESIGNERS' CONTRIBUTION

When we expect IT to enter social as well as private everyday life environments, we have to take into account the social visibility of technology. If IT artifacts are not confined to single user and desktop anymore, we need to support users' control and creativity over their environments, as well as their symbolic and communicative use of artifacts. That means, IT artifacts must meet users' need of self expression in the same way objects of our material culture have done so far (e.g. furniture, pictures, clothes, accessories). Furthermore, they must accommodate the need of self expression of different users, who synchronously or asynchronously inhabit such environments (e.g. inhabitants of a household, who can have different ages, roles, rooms).

In this paper I discussed the expressive potential of design to shape and establish meaningful relationships between people and their environments. Design research can also contribute to the identification of users' benefits and elicitation of users' needs by creating semi-finished and open artifacts: these can establish a communication with stakeholders and users and trigger reflection. Towards a beneficial collaboration of designers in the research community some issues remain open though, that make such contribution still difficult.

The dynamic nature of instrumented interactive environments and the increment of users' control over information raise new challenges for designers: designers' control over the final product and experience diminishes. The creation of semi-finished and/or open artifacts which convey the representation of designers' vision and stimulate users' imagination can be beneficial in the early development phase. This can give an insight of users' attitudes towards designers' visions, thus helping in the selection of design alternatives before major expensive developments.

Another aspect to keep in mind is that designers focus on the communication of a vision, which is inevitably bearing values. Artifacts, even semi-finished and open ones, establish a communication between designers and users which is initiated and somewhat stirred by designers, through the representation of a concept. Recognizing this aspect is essential for the identification of designers' responsibility, as well as for the justification of qualitative research methods.

The hybrid nature of intelligent environments, encompassing physical and digital layers, asks for creating, representing and communicating design visions that span across digital and physical worlds. Design professionals are often trained with a focus on one of the two aspects, and need to find new ways of expressing and sharing their ideas about holistic experiences. The collaboration with engineers becomes crucial in the establishment of new communication techniques for the exchange of ideas: between designers and engineers in a first place, and between designers and users as well.

Designers' approach to communication is based on artifacts and representations, rather then on explicit articulation of knowledge. This implies that design, as well as other disciplines involved in the HCI research, need to make an effort to communicate with each-other. On the one hand designers need to be educated to extrapolate, structure, and abstract knowledge and principles from the artifacts they design, and the know-how they instantiate. In other words, they need to understand research tools and methods. On the other hand, the other disciplines within HCI need to develop a culture of interpretation [3], in order to recognize and exploit the designers' contribution.

On a more general level, alternative forms of communication, which are not necessarily based on traditional textual forms, can provide a more accessible context for designers' expression of knowledge. The institution of submission categories for demos and videos, as well as for design cases in several HCI conferences is already a step in this direction.

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