Collaborative Practices that Support Creativity in Design

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Abstract. Design is a ubiquitous, collaborative and highly material activity. Because of the embodied nature of the design profession, designers apply certain collaborative practices to enhance creativity in their everyday work. Within the domain of industrial design, we studied two educational design departments over a period of eight months. Using examples from our fieldwork, we develop our results around three broad themes related to collaborative practices that support the creativity of design professionals: 1) externalization, 2) use of physical space, and 3) use of bodies. We believe that these themes of collaborative practices could provide new insights into designing technologies for supporting a varied set of design activities. We describe two conceptual collaborative systems derived from the results of our study.

Introduction

A typical design studio (professional or academic) has a high material character – in the sense that it is full of material objects and design artefacts; office walls and other working surfaces full of post-it notes, sketches and magazine clips for sharing ideas and inspiration; physical models and prototypes lying on the desks and so on. The physical surroundings of a design studio and the persistence with which different material artefacts are arranged and represented are important to the design activity and serve as organizational memory (Ackerman and Halverson, 1995) and distributed cognition (Hutchins, 1995) for design teams.

This ecological richness of design studios stimulates creativity in a manner that is useful and relevant to the ongoing design tasks. Additionally, designers do not work in a stereotypical or mechanical fashion when designing interactive products. Designers tend to be innovative, creative and often playful in order to collaborate and successfully meet the demands of building new products and services. Methods frequently used by designers such as role playing (Boess, 2008), body storming, design choreography (Klooster and Overbeeke, 2005) and so on are not limited to problem solving but also include understanding interactional and experiential qualities in designing interactive products.

The role of collaboration between co-designers is critical to a design studio's creativity. As Engeström (2001) explains, the source of creativity is not inside a person's head, but it emerges in the interaction between a person's thoughts and his socio-cultural context. In design studios, communication and coordination between co-designers depend as much on different visual and physical aspects as they do on verbal aspects. During a typical collaborative design session, the type of information that is communicated between designers is multimodal, ubiquitous and touches the artistic, emotional and experiential side of the designers' thinking, in addition to their instrumental and practical reasoning.

Building on our previous work (Vyas et al. 2008; Vyas et al. 2009 and Vyas 2009), in this paper we focus on understanding collaborative approaches utilized by designers to aid creative support for ongoing design projects. We studied two industrial design departments over a period of eight months and explored three broad themes of collaborative practices. These are 1) externalization, 2) use of physical space, and 3) use of body. The *externalization* theme encompasses any kind of design knowledge represented onto three-dimensional, physical medium (e.g. sketches, models, prototypes) that can be used for establishing common-ground amongst co-designers. The *use of physical space* theme refers to a kind of ecological setup within a design studio, full of different types of design materials and artefacts (e.g. sketches, posters, timetables, to-do lists) that help co-designers organize, coordinate and manage their design work. The *use of body* theme refers to a collection of design practices where designers' bodies play an important role in exploring and communicating design knowledge with a group of co-designers. These broader themes encompass both pragmatic and instrumental factors related to design activities as well as inspirational factors that are important to aid creativity in the design profession. These themes are not mutually exclusive; on the contrary, their combinations are frequently used and they are frequently complemented by the other generic ways of communicating, such as, talking, overhearing and so on. Depending on designers' points of view, the rationale behind applying these collaborative practices range from clearly defining design problems, exploring new possibilities, easing communicative difficulties, to developing a communication language with co-workers.

Our motivation to do this kind of research is multifaceted. First, although research in HCI and CSCW has increasingly started focusing on the 'design' of interactive and collaborative technologies, 'design as a profession' is largely untouched as a subject of empirical study, with a few exceptions such as (Jaccuci and Wagner, 2003; Schmidt and Wagner, 2002; Robertson, 1997). However, we do acknowledge that there has been a sufficient amount of work done in developing tools and techniques to support design (Arias et al. 2000; Everitt et al. 2003; Hartmann et al. 2006; Maldonado et al. 2006). Secondly, as a part of creative industry, design cannot be easily formalized or rationalized to a specific set of activities, tasks or other kind of stereotypes. For example, traditional ways of communicating and collaborating may not be so important for the design profession (as we will see later). Hence, there is a need to understand how designers differ from other knowledge workers in terms of their working practices. Thirdly, we believe that in order to better support designers' work and to develop new collaborative technologies, we need to understand how collaborative practices of designers enable creativity in their everyday work. An empirical investigation is required that specifically looks into the ubiquitous, collaborative and material nature of design practices.

In the rest of the paper, first, we will briefly describe background work that signifies the importance of embodiment in design work and some examples of augmented design environments. Next, we will describe our approach and methods used in understanding design environments in two industrial design departments. Next, we will describe the results of our study, focusing on the three themes of creative collaborative practices. And in the last section, we will discuss the implications of our results and provide a conceptual vision for developing technology to support collaborative design.

Related Literature

Our everyday communications and coordination acts go beyond linguistic signals and involve the use of material artefacts, locations and physical spaces (Clark, 2005). In fact, CSCW studies have increasingly shown the importance of material artefacts in coordinating distributed and co-located work (Hutchins 1995; Schmidt and Wagner, 2002; Sellen and Harper, 2002). Several authors (e.g., Kidd, 1995; Kirsh, 1995; Vyas, 2009) discuss how individuals intelligently make use of physical space and its affordances, in order to establish communication within a group. Advocating the use of ethnographic studies for designing systems, Randall et al. (2007) indicate three major aspects of artefacts that are relevant for understanding group work: ecological, coordinative and organizational aspects.

Amongst the empirical work on understanding design practices, Tang's (1991) classic study focuses specifically on collaborative drawing, using observational video-tapes of three to four people collaborating at a table. Tang identifies several

features of collaborative work activity that should be taken into account when designing collaborative technologies. These are: 1) the importance of gestures, 2) drawing space as a resource for collaboration, 3) the importance of the process of collaborative drawing itself (instead of the final result), 4) recognizing the mix of simultaneous activities, and 5) the spatial orientation of collaborative workers. Jacucci and Wagner (2003) study the everyday practices of students at an architecture design laboratory. Their focus is on integrating ubiquitous computing technologies to support students' embodied interaction and contextualize these technologies to architectural design situations. Their ethnographic research shows the importance of material richness and diversity of material artefacts. They also register the distributed character of architecture learning and the use of space as a resource for collaborative interactions. The coordinative nature and the resourceful materiality of informational artefacts such as architectural maps or physical models are echoed by the work of Schmidt and Wagner (2002). In their later work, Jacucci and Wagner (2007) show how the materiality of informational artefacts plays an important role for creativity.

Hornecker (2002) uses an experimental setup where a group of co-located participants uses an assembly of three-dimensional objects in order to carry out paper prototyping as a design activity. Generating implications from a set of video recorded paper-prototyping sessions, her goal is to develop a graspable interface using table-top display technologies in order to support co-located design work. She focuses on the role of embodied actions such as use of gestures, parallel activities of participants and alignment of gestures with design artefacts and talks. A similar study is done by Robertson (1997), who develops a taxonomy of embodied actions of designers while working on cooperative design projects. She suggests that the public availability of different artefacts and embodied actions of distributed participants in a cooperative process could support communicative functions. She also argues that flexible and mobile access to the publicly visible information could improve coordination.

On the technological advancements in supporting design activities, we observe that researchers have focused on supporting embodied interaction in their technologies utilizing tangible and ubiquitous computing. Envisionment and Discovery Collaboratory (EDC) is one such platform that integrates two working spaces where stakeholders can incrementally create a shared understanding through collaborative design (Arias et al. 2000). The Distributed Designers' Outpost (Everitt et al. 2003) is a remote collaborative system that allows designers to use physical post-it notes to support discussion while designing websites. The application allows synchronous communication between distant designers through the use of 'transient ink' and 'remote shadow' mechanisms in order to coordinate design tasks.

Maldonado et al. (2006) developed the iDeas design ecology, a collection of tools that combines a browser for text and sketch-based design content, mobile

input mechanism for field observation data, and a vertical surface for collaborative creation and presentation. The d.tools toolkit (Hartmann and Klemmer, 2006) supports iterative prototyping of information appliances by allowing integration of design, test and analysis activities.

Understanding Collaborative Design – Our Approach

We investigated collaborative design practices in two industrial design departments in academic settings. Our ethnographic approach was informed by ethnomethodology (Randall et al. 2007). We intended to understand the everyday work practices of designers, methods and procedures they use to support their work and the resources they use to make sense of their design world. We used naturalistic observations, contextual interviews and video recorded collaborative design sessions of designers and design students. Our fieldwork lasted approximately eight months.

In the naturalistic observations, we studied the collaborative aspects of the design studios. Our goal here was to understand the natural circumstances of designers' collaboration, the tools and methods they use, and how the creative process of design is achieved. We had contextual interviews with 10 Master's students of industrial design and 5 designers / design researchers. We asked questions on individual ways of designing and on how designers understood creative ways of working. We asked how they brainstorm, what methods they use to come up with design concept, how they convey ideas to each other, their preferred tools for designing, the perceived advantages of using such tools, and so on. We took opportunities to record design sessions of groups of student designers. In some cases, we were participant observers collaborating with design students and recording their design proceedings.

In our analysis we identified three major themes of collaborative practices amongst the designers: *externalization*, *use of physical space*, and *use of body*. Our aim here is to show how creativity becomes an integral part of designers' work when they apply these collaborative practices while working in groups. We also want to stress that these collaborative practices are not used separately in all the cases and are often used in combination with each other.

Themes of Creative Collaborative Practices

In the following, we give specific attention to the three themes of collaborative practices of designers: 1) externalization, 2) use of physical space and 3) use of body. Figure 1 shows a typical scenario of a design session, where all three themes of collaborative practice play their parts.

Figure 1: A typical collaborative design session at an industrial design department.

Externalization

This theme was frequently observed as a major resource for establishing and enhancing creativity as a collaborative process. Externalization carries a broad range of design practices and activities: externalization of thoughts, of ideas and of concepts on a range of physical media. Artefacts such as paper sketches, drawings, posters, cardboard, clay or foam-models, and physical prototypes are examples of design externalization. Designers' externalizing practices vary over time (at different stages of design), in modality (from paper sketches to physical models), in purpose (exploratory or definitive), and are subject to individual preferences. In a single design project, design practitioners produce and use a plethora of design artefacts to support their work. These are constructed and used in and through an ongoing process of design. Within the context of industrial design, the externalization theme can be seen as a 'mediator' as well as a 'product' of cooperative design.

CSCW studies have shown that artefacts such as papers play a critical role in supporting social interaction and collaboration (Sellen and Harper, 2002). For designers, paper-based sketches have also shown coordinative advantages (Baskinger, 2008). With examples from our fieldwork we will describe how externalization plays a collaborative role in different activities and aspects of design: exploration, thinking by doing, coordination, and empathy and experience.

Exploration. Designers explore new ideas and concepts at various stages of their design cycle using different material artefacts such as sketches, mock-ups, models, and working prototypes. The goal here is to spend reasonable effort in order to get a partial result quickly. As one designer commented, "*in order to make design decisions you need to do explorations and for that you need to make*

different levels of prototypes". In design, everyday externalization practices involving sketches, foam or card-board could help designers explore new design ideas without too much effort. These types of external representations help designers to establish a creative sensibility. For example, sometimes sketching is used for visualizing designers' thinking as it stimulates creativity not only within their head but also with their hands. Figure 2a shows a brainstorming session where a group of designers are externalizing their ideas on post-it notes and at the same time giving a formal structure and category to their material. As one designer commented, "*Sometimes it is also useful to get something out of your head* (externalize the ideas). *When I have a lot of ideas and I know that some of these are not good, I just try to make a sketch of all of them and so that even some less important ideas are stored somewhere. I think it's a good thing that it gets me going.*"
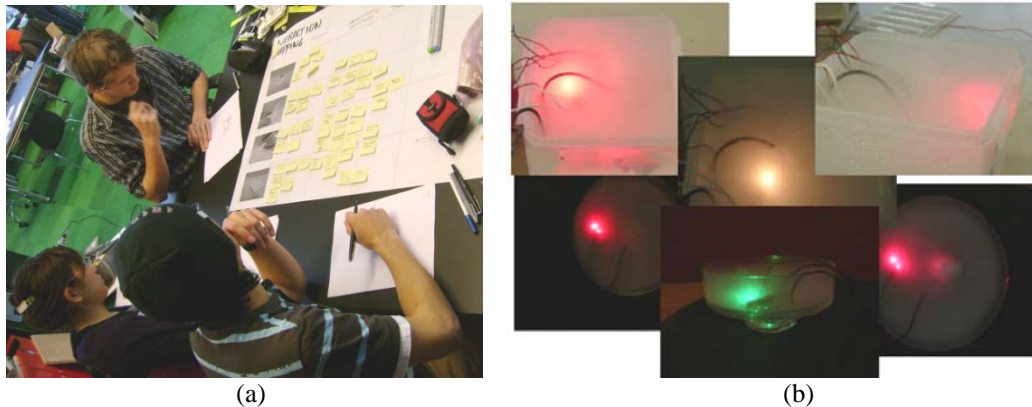

Figure 2: A structured brainstorming session using post-its to explore new ideas (a). Explorations of the effect of combining smoke and light (b).

We also observed that there are things that designers cannot easily envision through only drawing or sketching. They have to practically apply their ideas through different forms and textures of design models and prototypes to get a feel of their products. This kind of physical model allows designers to extend their mental conceptualization of their product to a sensory one. Figure 2b is an example of exploring the effect of smoke and different light colors in different shapes of glass. The idea here is to explore which combination would be suitable for a given situation. This designer explains that "*there are certain things that you cannot envision in a normal situation, things like "smoke". So in order to understand the behavior and interaction with smoke and utilizing it into design you have to build some things and play with it.*" By joining the exploration of smoke with different kinds of lights, the designer explains, "*even by playing with a light I can get several ideas about new ways of interacting with lights, like blinking, fading, making patterns, so expressing new behaviors through the use of lights and different colors of lights. This opens up my visualization skills and*

provides new spaces for design. In this case if I just sketch this smoke with light, I wouldn't get that feeling. Here you can play with your hands, move the smoke around, this is a very different kind of design expression and gives me a different feeling."

Thinking through Doing. Designers communicate through a varied set of design representations often involving different materials, modalities and scale. To an extent, the whole design practice progresses through the use and manipulation of these representations and iterative refinements of both the conceptual and physical forms of products to be designed. Through externalization designers can visualize their ideas and concepts by actually creating them (putting things into practice) and not just by thinking about them. The physical activities and tasks that designers carry out allow them to think about the design of their products in a better way. During an iterative design process design artefacts such as sketches or models 'talk back' to designers (Schön, 1983). The epistemic knowledge developed during the process of constructing different design artefacts and externalizing design ideas leverages the way designers deal with elements of surprise and unexpectedness.

(a)   (b)

Figure 3: Externalizing design knowledge on different materials such as paper based sketches (a) and physical models using clay, foam, cardboard and plastic (b). (Photo: courtesy of Connie Golsteijn)

Our fieldwork on designers underscores the centrality of 'thinking through doing' (or thinking though externalizing). It was observed that a single design team would collectively develop an average of 50 to 100 external representations of their design ideas, depending on the project. These vary from paper based sketches or cardboard models to physical models. Because different styles and levels of fidelity of a representation yield different perspectives, meanings and experiences, externalizing ideas through a variety of prototypes affords a richer understanding of a design. Figure 3 shows two different examples where different design representations are used to support discussions. Figure 3a shows a design group using a collection of paper based sketches, whereas figure 3b shows a table

full of physical models made of clay, foam, cardboard and plastic. Being able to create more than one representation and alternatives of an idea and to try them out is in fact a major requirement for supporting creativity (Fischer, 2004). The thinking though doing theme suggests that the effort invested in developing different design alternatives helps co-designers to compare and judge important aspects such as the difficulty of building the final product.

Coordination. Several CSCW studies have shown that material artefacts play an important role in coordinating co-located and distributed activities (e.g. Sellen and Harper, 2002; Hutchins, 1995). Externalization of design ideas supports coordination within a team. The materiality of design artefacts provides information about the way they are created, used and manipulated, as well as about the process of design. Importantly, the temporality serves not only as indicative of different stages of a design process, it also serves accountability (planning, managing, budgeting, and so on) during the design work.

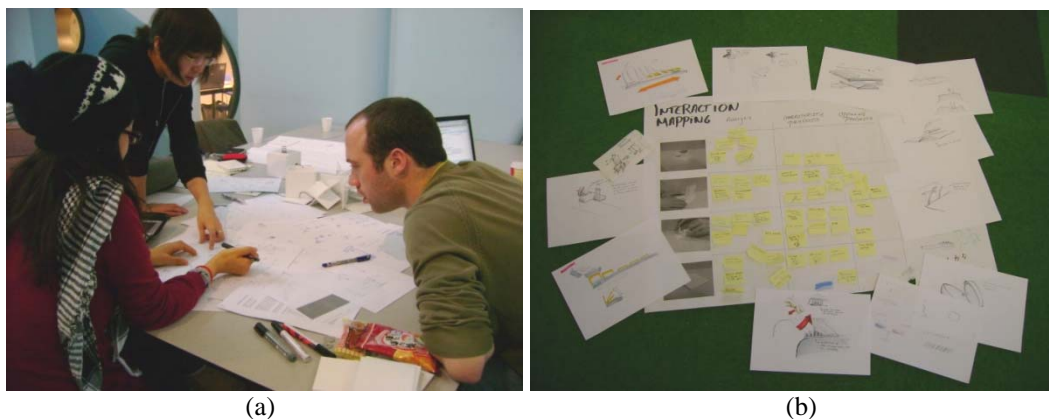(a)   (b)

Figure 4: Group discussion of set of sketches (a), and result of a brainstorming session (b).

Different externalization techniques lead to creative methods of communication within a design team. Externalizations support creativity as they provide opportunities for others to interact with, react to, negotiate around, and build upon an idea. Externalizations contribute to a common language of understanding amongst a group of designers. For example, figure 4a shows a group of designers discussing different sketches at a table. Figure 4b shows results of another brainstorming session where the cooperative nature of design artefacts helped to develop new alternative concepts. The important issue here is that the materiality of different design representations can afford and trigger different collaborative actions in the team.

Empathy & Experience. In our field study, we saw several examples where designers created design representations based on observations of the real users. They tried to provide as much empathy towards the users through the development of such representations. One of the most powerful human capabilities relevant to designers is the intimate incorporation of an artefact into

physical experiences to the point where people perceive that artefact as an extension of themselves; they act through it rather than on it (Klemmer et al. 2006). Additionally, different design materials and artefacts allow direct and bodily engagement and hence broaden communicative resources by evoking sensual experiences. The multi-modality and ability to support and convey information through all senses, makes the use of a design artefact experientially rich (Vyas et al. 2009). In the case of joint design activities, co-workers do not just interact with these artefacts when they are designing, they actually get the feeling and experience each other's activities through these artefacts. The communication channels that are established by these multi-modal artefacts go beyond facilitating basic task-oriented activities.

Use of Physical Space

This theme refers to how design practitioners utilize their physical surroundings within a design studio in order to support collaboration and creativity in their work. In both of the design studios that we studied, we saw design teams use their office walls, whiteboards, clipboards, wooden panels and so on as carriers of their design-related information. The types of information that are attached to these spatial objects have instrumental and productivity related functions and can be seen in the form of design ideas, sketches, to-do lists, project-related information, work-in-progress data and other organizational details. At the same time, they also carry inspirational, provocative and other non-instrumental details such as posters and innovative design sketches. The way information is represented in the space provides indication about collaborative and methodic practices of designers (Vyas 2009).

Figure 5: An example of creative ecology in a design studio.

Figure 5 gives a glimpse of a section of a design studio where a design team has used clipboards, large card boards and movable tables to develop a creative environment. In addition, there is information about project plan, post-it notes, design sketches on the clipboard, as well as the prototype on the table. An environment such as this establishes a 'creative ecology' within a design studio both at personal and social level. In the following, we will discuss how arrangements such as these help in establishing creativity.

Elaborate the Problem. One of the reasons to utilize space in such a way is to elaborate and divide design challenges so that detailed descriptions of different aspects of design can be generated, which in turn would help in resolving a particular situation. The way physical space allows the representation of design tasks can affect designers' reasoning abilities and performance. As one designer suggested, "*I normally try to visualize all the material and data that I collected from my user studies and try to find out patterns and explore design opportunities from this data. I then make my own sketches and models and keep all these in a way that can help me find out new ideas*".

(a)   (b)

Figure 6: A shared design environment, with pictures of different field studies and observations on the walls and desk (a). Detailed personas on a wall of a design studio (b).

Several examples of this were seen in both of the design studios. Designers keep, for example, pictures from ethnographic or other field studies on their office walls and around their desks (figure 6a), or develop persona archetypes of their potential user groups and stick them on their shared working spaces (figure 6b). The aim here is not just to solve a design problem but to collect greater and useful insights into a given situation so that solutions can be envisioned.

Awareness. Within an ongoing design project, designers deal with a plethora of design materials, and being aware of different 'happenings' is an important issue. We observed that the way designers keep project-related design materials on different spatial objects within their studios improves the visibility and provides an overview of the work being carried out. Understanding how design artefacts within a work environment are organized, configured, manipulated and

handled supports the awareness of co-workers' activities and, hence, contributes to the coordination of work. Design iterations, methods, and conventions can be easily extracted when design artefacts and related materials are kept in public visibility using physical space. The visibility of design activities is also manifested in and through the use of these artefacts. At the same time such a creative space could provide opportunities to reflect on the ongoing project and to allow designers to change, combine or divert aspects of their design process.

Organize and Manage. Design being a collaborative process requires organizing and managing the work of co-designers. The spatial aspects within design studios also play a role in supporting the organization and management of design projects. Figure 7 shows two examples (a & b) where design teams have used clipboards and movable drawing boards to show information related to project plans, data generated from brainstorming sessions, design concepts, work division within a team and to-do lists. Each individual piece of design-related information has a strong, even explicit link to some aspect of the project at hand. The ecology of these pieces information creates an information rich environment needed to stimulate creativity and to develop novel ideas.

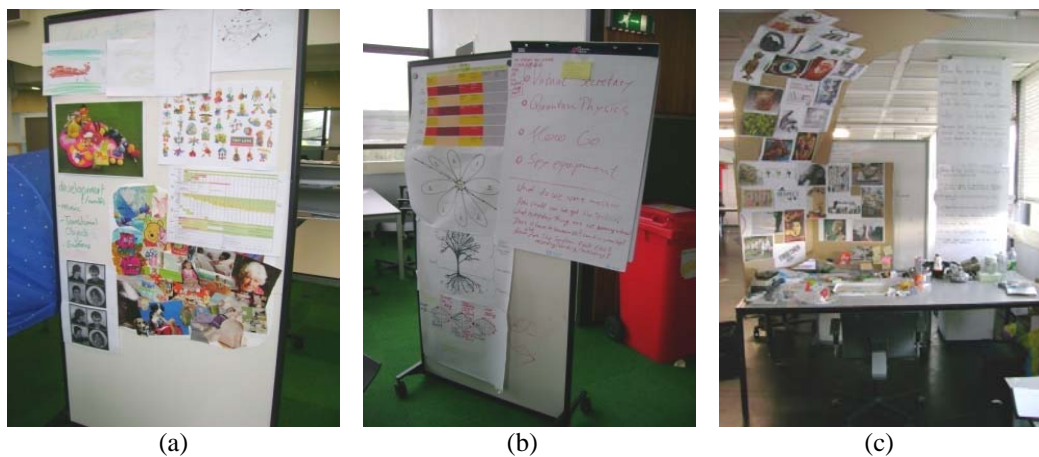|		
(a)	(b)	(c)

Figure 7: Shared clipboards full of design-related materials to organize and manage ongoing projects (a & b). The personal workspace of a designer (c).

Personal vs. Shared. The way different information and design artefacts are arranged within design studios establishes a vague distinction between personal and shared spaces. The above figures 7a and 7b show a physical space that is shared by a group of designers. However, designers also have their individual working space that they organize based on their own personality and reasons. As one of the designers commented about his private space, "*the space allows me to organize my work and get reminded what I am doing daily. Also for the purpose of communicating with my peers I can very easily show what I am doing.*" As can be seen in figure 7c, these artefacts are indicative of different phases of the design process, the current state, and future planning. Another designer commented,

"*depending on the phase of the project, I arrange my surroundings. It's important for me to have these artefacts around so that I can register where I am at in the project*". Hence, these design artefacts were markers for reminding. Personal spaces also allowed designers to create a portfolio-like arrangement of their workspaces expressing an identity or self-image.

Use of Body

During ongoing design projects, designers accomplish activities and tasks not only through their internal cognitive processes but by utilizing cooperative 'embodied' actions (Robertson 1997). The third theme that we discuss here is about how the specific use of designers' bodies helps in establishing creativity in collaborative design practices. The use of the body theme is central to externalization and utilizing the space (the above two themes) in all design activities. Designers creatively make use of their bodies while talking, while explaining a design sketch or in referring to spatial arrangements within a design studio. While the use of gestures and other bodily representations for discussing design ideas is common in design studios, there is an increasing use of design methods such as role playing, body storming or design choreography in groups (Hummels et al. 2007). Using these methods, designers explore and experience design possibilities for themselves, intentionally make these ideas public and allow other designers to reflect on these ideas. Here the design cooperation is achieved by the mutual perception of these actions as the basis for the ongoing creation of shared meanings in a particular design task. The use of bodies can be seen in different design stages to support different needs. In the following we will explain how the use of bodies helps in creativity.

Figure 8: Exploring design possibilities through performances. (Photo: courtesy of Rob Tieben)

Exploring Interactive Concepts. It has been suggested that bodily movements are suitable as a design technique, as our bodies convey emotions as well as geometry and interactions (Hummels et al. 2007). Role play methods allow designers to imagine and empathize a given design challenge. A physical activity is a primary source here to explore new possibilities. In our fieldwork we found that many of these bodily actions were aimed at better understanding of the design task context and at exploring new possibilities. Figure 8 shows two examples of exploring design possibilities. Here, the participants, using different bodily patterns, are exploring the possible behaviors of the product to be designed. The vividness of these experiences and the bodily understanding of a given design situation help designers to make better design decisions (Buchenau and Fulton Suri, 2000).

Improve Communications. Our verbal languages may not be enough when communicating issues related to complex technologies. While designing new technologies or products, designers have to think about out-of-the-box ideas that may be difficult to articulate using verbal means. One of the main objectives of applying role play methods is to communicate early design ideas and concepts in an engaging and participative way that could establish common-ground for the group of designers (Buchenau and Fulton Suri, 2000). Additionally, many product designers need to deal with issues such as branding, marketing and advertising. Methods such as role play help in dealing with all these issues in one package – that requires a combination of functionality, expression and communication.

Studies have shown that gestures, in addition to their purely communicative role, help lighten cognitive load when a speaker or performer uses them in combination with speech (Tang, 1991). Through role playing, a performer's ability to map his/her actions to certain features or tasks of design could help in understanding the envisioned product.

Exploring new Experiences. Supporting appropriate user experience is amongst the main goals within the design profession (McCarthy and Wright, 2005). Our physical bodies play a central role in shaping human experience in the world, in understanding of the world, and in interaction with the world (Klemmer et al. 2006). In addition to exploring new ideas and improving communication possibilities, we also observed that the use of role play and other participatory methods provided new perspectives on bodily experiences. When designers enact a particular scenario, they go through a set of emotional and experiential "phases" that not only make their actions personally meaningful but also lead them to envision how a potential experience should be.

Improving Design Practices. Echoing the claims of Fischer (2004), we observed that being able to move around the design environment and to interact with different design-related artefacts and with other designers can help in the understanding and learning of creative designing. This was in fact an important rule-of-thumb in one of the design studios that we visited. One of the professors

of the industrial design department frequently advised designers working in the studio to "*move around and don't just sit at the desks*" to generate creative ideas.

Figure 9: Design students collaboratively sketching – influencing and inspiring each other.

During the interview sessions with professional designers, we learned that on several occasions designers brainstormed by simultaneously drawing quick sketches and doodles on large sheets of paper in order to generate quick design ideas. Figure 9 shows design students at an industrial design department collaboratively exploring new ideas on a large sheet of paper. In close proximity, designers can influence and inspire each other and at the same time adapt to each other's sketching styles. This theme suggests that creativity is an applied phenomenon, in full, creativity can be established by practicing and doing things in the real world, where bodies play a critical role.

Discussion and Design Concepts

The ethnomethodological approach allowed us to understand the current practices of designers to support creativity in their ongoing design work. In particular, the examples that are discussed in this paper point to the critical role of 'material collaboration' in supporting and enhancing creativity in the context of cooperative design. The three themes related to collaborative practices of designers that we have discussed here, namely, externalizing, use of space and use of bodies, provide insights into how material and physical signals can trigger creative thinking. We believe that there are important implications for the development of collaborative technologies for supporting professional designers. In the following we will describe these implications.

Spatial flexibility is an important factor for supporting group creativity of designers. It was apparent in our examples that designers develop a multitude of

design artefacts in the form of paper sketches, drawings, physical models and so on. The way designers keep these artefacts and organized them in their workspace affects their work organization, communication and coordination practices. It is this spatial flexibility of, for example, sticking sketches and drawings on a shared office wall or keeping physical models of different materials on a table that allows designers to discuss, criticize and explore new possibilities of their design work. In order to provide technological support for spatial flexibility, we need to think beyond desktop computers. Jaccuci and Wagner (2003) made an attempt to support spatial flexibility via mixing real work objects with virtual ones to support learning and collaborating amongst students of architecture.

Archiving materials used and produced during design processes helps co-designers get back to them whenever they need. There is creative value in allowing designers to associate and connect different design artefacts. We observed in our fieldwork that designers attach paper based sketches, drawings and posters to their vertical surfaces for different purposes, creating a technological environment that allows designers to archive these design materials in such as way that could lead to supporting creative thinking.

Encouraging movement is an important aspect for aiding designers' collaborative creativity. As it was seen in the examples, designers' physical movements during explorative design stages and while using methods such as role playing or body-storming, support creativity in group sessions. Supporting the call for Design Movement (Hummels et al. 2007), we believe that technology should not hinder designers' physical capabilities but, on the contrary, should encourage freedom.

Sustaining ubiquity of design practices, especially when people collaborate from remote locations, could be a challenging task for developers. As was observed in our fieldwork, information related to a design project can be found in physical space and in material artefacts, as well as in designers' ability to utilize these material aspects. We believe that technologies that support live transmission of audio-video links may be able to support designers' conversations, but the pervasive nature of design practices requires the creation of technologies that go beyond these conversational paradigms.

Supporting thick practices of designers is a design challenge that should be taken into account. By this we mean that any new technology should acknowledge and take into account the primacy of real-world design practices. Technology should not just bring new ways of working but instead improve flexibility for the designers to use their methods. In this sense, a technology should carefully integrate physical and digital worlds to enable the improvisation of practices that the real world could offer.

Keeping these implications as a base, we have developed two conceptual systems that could potentially be used to support collaborative design activities. These are 1) the resource sharing concept and 2) the live discussions concept.
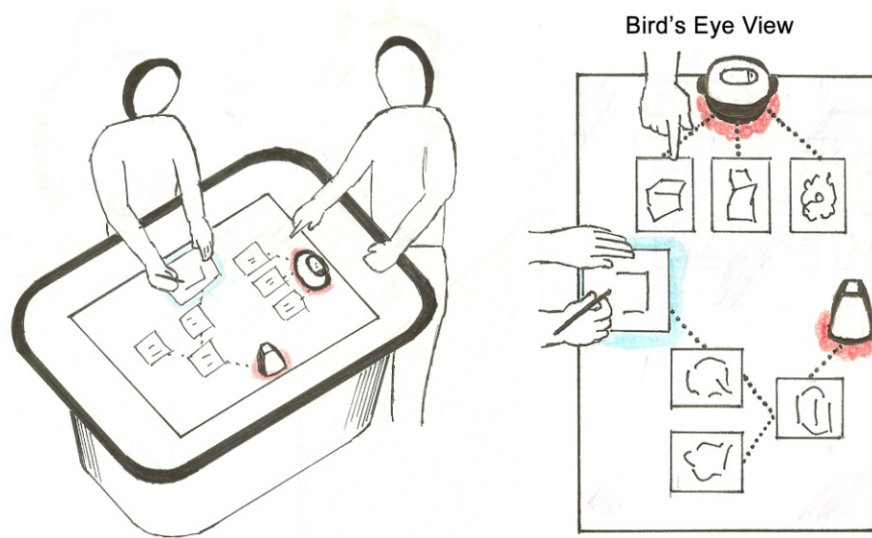
Resource Sharing Concept

Figure 10: Resource Sharing concept on a table-top workspace

The first of our concepts, Resource Sharing (figure 10), allows creative collaboration between designers in a co-located situation. The Resource Sharing concept uses a tabletop interface which allows designers to discuss and share design resources related to their products or prototypes. The tabletop interface can generate the design history of a physical product once it is kept on the surface of the table. The table shows the digital versions of the product ideas, associated sketches, annotated drawings and other historically important details in a hierarchical format. The table supports the use of multiple physical products or prototypes. As can be seen in the figure 10, using this tabletop interface, designers can look back in time, re-view the options they considered and reflect on them. The tabletop interface also allows designers to make new sketches on the interface based on what they are currently discussing in a design session.

This concept uses tabletop technology to allow designers a kind of spatial flexibility compared to a typical desktop based system. This spatial flexibility allows designers to collaboratively access multiple design artefacts (e.g. sketches) at the same time carry out brainstorm activities. In a sense, the table-top interface provides a mixed-reality interface to discuss real-world objects and associated digital artefacts, and it allows designers to sketch new design ideas on the surface of the table. The ability to connect, associate and compare multiple design artefacts on the table surface could enable designers' creative brainstorming activities. The tabletop interface does not impose any substantially new practice, it just allows new ways of interacting and storing design ideas in the table.

Realizing this kind of technology may not be too difficult as existing tabletop technology such as Microsoft Surface or Philips Entertaible can be used.
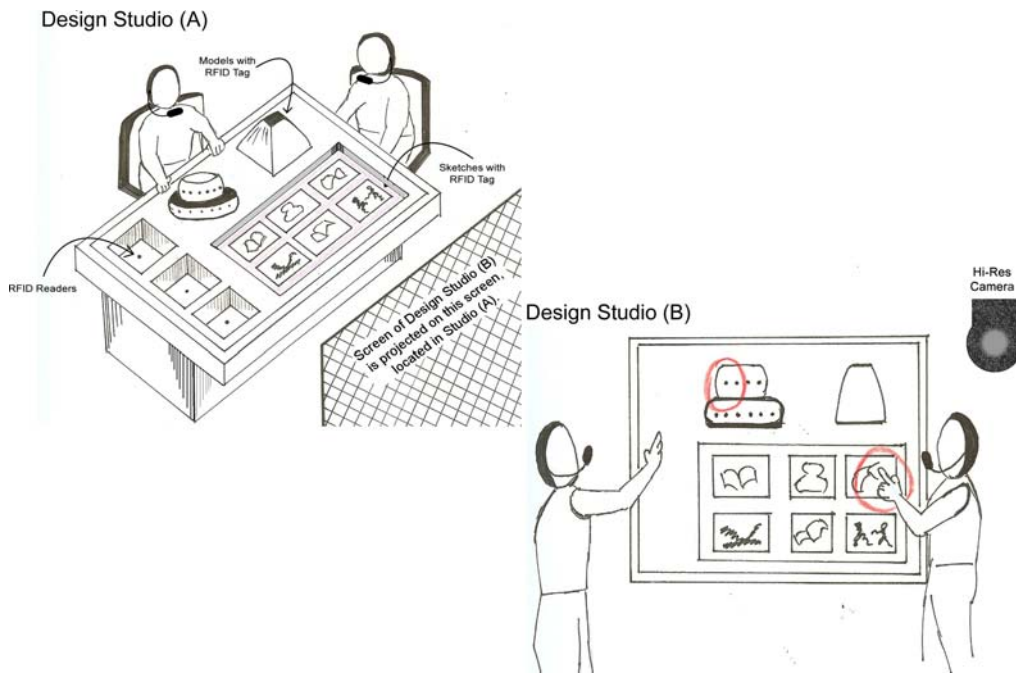
Live Discussions Concept

Figure 11: Live Discussions concept

The second concept, Live Discussions (figure 11), focuses mainly on remote collaboration, allowing designers to discuss three-dimensional and physical objects or prototypes as well as two-dimensional paper-based sketches without loosing information. As can be seen in the figure 11, design studio A has a table with dedicated planes (surface spaces) to allow communication of different types of design artefacts. Design artefacts have a RFID tag attached and different planes on the table are equipped with RFID readers. Design studio B is located at a distant place with other members of the same team. Studio B has a large-screen touch display where the view of the table in studio A is shown, with the help of RFID tags and readers. The dedicated planes on the table help to adequately represent the two-dimensional and three-dimensional information. In Studio B, designers can point, annotate or draw on a particular part of a design object and simultaneously communicate via microphones. Studio B is equipped with a hi-resolution camera that shows the live feeds of Studio B onto a display located in Studio-A. The concept is partly based on the work of Everitt et al. (2003), where design brainstorming was made possible through the use of post-it notes.

This concept is based on implications from our fieldwork. By allowing spatial flexibility though the use of a dedicated design table we could allow to discuss both two-dimensional and three-dimensional objects and to brainstorm over a distance.

Conclusions

The observations and ideas discussed above do not address the entire range of practices of the design studio culture. The three themes of collaborative practices that we discussed cover a broad spectrum of techniques that designers use to aid creativity in cooperative design. Clearly, creativity is a critical aspect of design and needs to be supported though technological means. What has been presented here is an account of how creativity is applied by the designers of the two industrial design departments. An account of real-world design practices such as this could be very fruitful when we are to design collaborative technologies.

This study reflects the embodied nature of design practices. Our work shows: 1) how different externalization techniques utilizing seemingly mundane and simple design artefacts such as sketches, post-it notes, and physical models within a design studio play a role in supporting designers' everyday creative work; 2) how the intelligent use of physical space of a design studio helps designers to think creatively about their design work; and, 3) how bodies of designers play a pivotal role in experiencing and envisioning design aspects. The rationale behind applying these collaborative practices ranged from clearly defining design problems, exploring new possibilities, easing communicative difficulties, to developing a communication language with co-workers.

References

Ackerman, M. S. and Halverson, C. (1999): 'Organizational Memory: Processes, Boundary Objects, and Trajectories'. In *Proc. of the 32nd Annual Hawaii international Conference on System Sciences*- Volume 1. HICSS. IEEE Computer Society, Washington, DC, 1067.

Arias, E., Eden, H., Fischer, G., Gorman, A., and Scharff, E. (2000): 'Transcending the individual human mind—creating shared understanding through collaborative design'. *ACM Trans. Comput.-Hum. Interact.* 7, 1 (Mar. 2000), 84-113.

Baskinger, M. (2008): 'Pencils before pixels: a primer in hand-generated sketching'. *Interactions*, 15, 2 (Mar. 2008), 28-36.

Boess, S. U. (2008): 'First steps in role playing'. In *CHI '08 Extended Abstracts on Human Factors in Computing Systems*. (CHI'08) ACM, New York, NY, 2017-2024.

Buchenau, M. and Fulton Suri, J. (2000): 'Experience Prototyping'. In *Proc. of Fourth Conference of Designing Interactive Systems* (DIS'00) ACM Press: NY, 424-433.

Clark, H. H. (2005): 'Coordinating with each other in a material world'. *Discourse and Society*, 2005, 7: 507-525.

Engeström, Y. (2001): 'Expansive Learning at Work: Toward an Activity Theoretical Reconceptualization', *Journal of Education and Work* 14(1): 133-156.

Fischer, G. (2004): 'Social Creativity: Turning Barriers into Opportunities for Collaborative Design.' In F. deCindio, & D. Schuler (Eds.), In *Proc. of the 8th Conference on Participatory Design Conference* (PDC'04) , Volume 1, ACM Press, NY, 152-161.

Hartmann, B., Klemmer, S. R., et al. (2006): 'Reflective physical prototyping through integrated design, test, and analysis.' In *Proceedings of the 19th Annual ACM Symposium on User interface Software and Technology* (UIST '06). ACM, New York, NY, 299-308.

Hornecker, E. (2002): 'Understanding the Benefits of Graspable Interfaces for Cooperative Use'. In *Proc. of 5th International Conference on the Design of Cooperative Systems* (COOP'02). IOS Press, Amsterdam, 71-87.

Hummels, C., Overbeeke, K. C., and Klooster, S. (2007): 'Move to get moved: a search for methods, tools and knowledge to design for expressive and rich movement-based interaction'. *Personal Ubiquitous Comput.* 11, 8 (Dec. 2007), 677-690.

Hutchins, E. (1995) *Cognition in the wild*. MIT Press, Cambridge, USA.

Jacucci, G. and Wagner, I. (2003): 'Supporting Collaboration Ubiquitously: An Augmented Learning Environment for Design Students'. In *Proc of 8th European Conference on Computer Supported Co-operative Work* (ECSCW'03), Kluwer Academic Publishers, 139-158.

Jacucci, G. and Wagner, I. (2007): 'Performative roles of materiality for collective creativity'. In *Proc. of the 6th Conference on Creativity & Cognition* (C&C '07) ACM Press, NY, 73-82.

Kidd, A. (1994): 'Marks are on the Knowledge Worker'. In *Proc. of CHI'94*. ACM: NY, 186-191.

Kirsh, D. (1995): 'The intelligent use of space', *Artificial Intelligence*, v.73 n.1-2, 31-68.

Klemmer, S. R., Hartmann, B., and Takayama, L. (2006): 'How bodies matter: five themes for interaction design'. In *Proc. of the 6th Conference on Designing interactive Systems* (DIS'06). ACM, New York, NY, 140-149.

Klooster, S. and Overbeeke, C. (2005): 'Designing products as an integral part of choreography of interaction: the product's form as an integral part of movement'. In *Proc. of 1st European workshop on Design and Semantics of Form and Movement*. New Castle, UK, 23-35.

Maldonado, H., Lee, B., and Klemmer, S. (2006): 'Technology for design education: a case study.' *In CHI '06 Extended Abstracts on Human Factors in Computing Systems.* (CHI'06) ACM, New York, NY, 1067-1072.

McCarthy, J. and Wright, P. (2004): *Technology as Experience*. MIT Press, Cambridge, MA.

Randall, D., Harper, H. and Rouncefield, M. (2007): *Fieldwork for Design – Theory and Practice*. CSCW series, Springer-Verlag London.

Robertson, T. (1997): 'Cooperative work and lived cognition: a taxonomy of embodied actions'. In *Proc. of the 5th Conference on European Conference on Computer-Supported Cooperative Work,* (ECSCW' 97). Kluwer Academic Publishers, Norwell, MA, 205-220.

Schön, D. (1983): *The reflective practitioner: How professionals think in action*. NY: Basic Books

Schmidt, K. and Wagner, I. (2002): 'Coordinative artefacts in architectural practice'. In M. Blay-Fornarino et al. (eds.): In *Proc. of the 5th International Conference on the Design of Cooperative Systems* (COOP'02), IOS Press, Amsterdam, 257-274.

Sellen, A. and Harper, R. (2002): *The Myth of the Paperless Offices*. MIT Press, MA.

Tang, J. (1991): 'Findings from Observational Studies of Collaborative Work', *International Journal of Man-Machine Studies*, 34, Elsevier, 143-160.

Vyas, D., Heylen, D., and Nijholt, A. (2008): Physicality and Cooperative Design. In *Proc. of 5th Joint Workshop on Machine Learning and Multimodal Interaction.* (MLMI' 08), Lecture Notes in Computer Science, Springer-Verlag. 325-337.

Vyas, D. (2009): Artful Surfaces in Design Practices. In *CHI '09 Extended Abstracts on Human Factors in Computing Systems*. ACM, New York, NY, 2691-2694.

Vyas, D., Heylen, D., Nijholt, A. and van der Veer, G. (2009): Experiential Role of Artefacts in Cooperative Design. In *Proc. of 4th International Conference on Communities and Technologies* (C&T' 09). Penn State University, PA, USA. ACM Press: NY.