INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN
ICED 05 MELBOURNE, AUGUST 15 – 18, 2005

# DESIGN FOR VERSATILITY: THE CHANGING FACE OF WORKSPACES FOR COLLABORATIVE DESIGN

A Larsson, P Törlind, M Bergström, M Löfstrand, L Karlsson

## Abstract

In a fiercely competitive business climate, which is increasingly characterized by global alliances, partnerships and outsourcing agreements, companies struggle to decrease the negative impact of geographic distance on development efforts. The role of workspaces for collaborative design is gaining considerable attention, and there is currently an increasing interest in moving from individual tools or technologies to a more inclusive view of collaborative workspaces. This paper reports on the underlying motivation and justification for a new collaborative design studio at Luleå University of Technology, Sweden. The studio provides a rapid-response environment, in which the significance of issues raised through ethnographic observations of engineering work can be evaluated and solutions offered.

*Keywords: Collaborative design, distributed engineering, team workspaces, design studies*

## 1. Introduction

This paper describes the rationale behind the design of the newest addition to a range of collaborative studios at the Polhem Laboratory, Luleå University of Technology, Sweden. The idea of investing in a new collaborative environment stems from the experiences and observations derived from several collaborative product development research and educational projects performed within the Polhem Laboratory over the last five years [1, 2, 3, 4]. Recent interdisciplinary work within our research center has inspired us to further explore the relationship between the social and technical aspects of collaborative work, which is under continuous investigation in the area of *Computer Supported Cooperative Work* (CSCW). By applying concepts from the ethnographic tradition to the context of our research center's profound understanding of engineering practices, it is believed that the potential to create collaborative environments and technologies better suited to the needs of both co-located and distributed engineering communities has increased.

The year 2000 was our first attempt at designing a research facility for collaborative work in Luleå, with a 7x2 m projection surface, high-end conferencing capabilities and a capacity of up to 50 people. It was concluded after intensive usage that the existing space is mainly suitable for large meetings and design reviews, though too rigid and inflexible for everyday design collaboration in smaller design teams.

The new, yet to be named, collaborative studio is envisioned as a space flexible enough to accommodate a wide range of co-located and distributed collaborative scenarios, while being rigid enough to also allow for realistic, everyday design-in-action and effortless research observation of those activities. As such, the new studio will be mainly created to meet three central challenges in the further advancement of collaborative engineering design.

- The problem of design researchers to study design collaboration in realistic settings and situations.
- The practical difficulty of letting design students experience distributed collaboration.
- The challenge of rapidly implementing and evaluating new technologies, tools, and workspace concepts.

The underlying motives for the layout and functionalities of the studio will be discussed in detail – what the key features are and how they are put into practice. In addition, the authors will present a selection of first generation design concepts of the tools and technologies that will be available in the studio space. Possible future directions of collaborative environments will also be proposed based on the findings from previous collaborative design case studies conducted with Polhem Laboratory industry partners.

## 2. Background: Workspaces in Transformation

Companies working with product development are continuously faced with the dilemma of not being able to do everything in-house, forcing them to form alliances, partnerships and outsourcing agreements. They struggle to decrease the negative impact of geographic distance on development efforts and further enhance current advantages of worldwide, multidisciplinary collaboration [1]. In addition, they are beginning to understand that the vision formed more than ten years ago of the *Virtual Corporation*, or the *Virtual Enterprise*, is rapidly becoming a reality as more and more companies move from traditional alliances and outsourcing partnerships to a *"…temporary network of independent companies – suppliers, customers, even erstwhile rivals – linked by information technology to share skills, costs, and access to one another's markets. It will have neither central office nor organization chart. It will have no hierarchy, no vertical integration."* [5] Unsurprisingly, the ways in which individuals and teams are working together in such organizations are quickly changing, as well as the needs for the spaces where they work.

Different organizations have different facility strategies, with new strategies continuously evolving together with the development and deployment of new collaborative methods and technologies. Some design teams work in assigned project spaces, while others work in individual workspaces closely connected to team spaces. Some spaces are dedicated to certain activities, such as videoconferencing or large group meetings, while other spaces are open and flexible to support on-the-spot collaboration in just about any context. Some spaces have to be pre-booked, while others are used on a drop-in basis. Regardless of specific strategies, people generally adapt to the available setting and tools, therefore it is crucial to recognize that the design of collaborative workspaces can create barriers to true collaboration as well as promote and support collaborative behaviors and relationships.

Future workplaces, workspaces and work environments have been the subject of considerable interest in recent years. There has been a general move towards projects that do not merely attend to individual tools or technologies, but rather take a more inclusive view of collaborative workspaces. Such comprehensive initiatives include the Fraunhofer IPSI's *Roomware* [6], Stanford University's *iRoom* [7] and UNC-Chapel Hill's *Office of the Future* [8].

In particular, the European IST programme in the 5th and 6th frameworks has contributed to a much wider conceptualization of workspaces for collaboration. EU 'roadmap' projects, such as *Future Workspaces* [9], have been conducted to guide the future directions of the overall European research programme with respect to where and how work is carried out. The wider

conceptualization introduced within such roadmaps starts with a conceptual move from workspaces as merely the physical space where a person works to *"…new forms of workspaces which support tighter integration with geographically dispersed business partners and virtual interfaces, which allow efficient collaborative working and promote social interaction between remote team members."* [9]

In keeping with this vision, it should be noted that while a three-dimensional space with a variety of spatial features will be designed, it will first and foremost be designed for the 'life and work' that will go on in the space. Hence, we agree with Harrison & Dourish's [10] distinction of *space* and *place*, where the former is a non-changing physical area, the latter a continuously changing environment based on how it is used. For example, a certain space can be used for many types of activities without any changes to its external structure.

> *"An office might act, at different times, as a place for contemplation, meetings, intimate conversation and sleep. So a place may be more specific than a space. A space is always what it is, but a place is how it's used."* [10]

The word *space* has been chosen rather than *place* throughout this paper, primarily because of our focus on designing a physical environment that promotes 'place making' and collaboration in both a physical (co-located) and virtual (distributed) setting. Thus, it is not merely a place being designed; it is the design of *opportunities* for people to make places within that physical environment [10]. This is also in line with Alexander's [11] notion of a *pattern language*, which focuses on the pattern of events people experience in a certain environment. For example, the pattern 'Flexible Office Space (#146)' describes how to design a space that is *"specifically tuned to the needs of people working, and yet capable of an infinite number of various arrangements and combinations within it."* [11, p.690] Rather than prescribing a specific layout, Alexander gives general design suggestions to help the designer understand the on-going activities in a particular space, and the tradeoffs the designer may have to consider.

Similarly, the transformation into workspaces of the future involves a greater understanding of how work is carried out in an increasingly globalized business environment and involves a greater attention to design as a highly social and collaborative practice [12].

Fundamentally, the tighter integration envisioned within *Future Workspaces* and *Office of the Future* implies a closer connection between the physical and the virtual, the social and the technical, and the local and the remote. Bridging all these factors is a massive challenge that is driving the design of the new collaborative studio as well as our overall research agenda to support collaborative work in global virtual enterprises.

The following two sections will describe some of the significant aspects related to workspace design and use that our research group is interested in, primarily with workspaces in two contexts: *collaborative design-in-action* (how design teams work) and *research on collaborative design* (how researchers study design teams). Both contexts are viewed with respect to co-located and distributed settings to underline the increasingly global outlook on collaborative work in virtual enterprises.

## 2.1 Workspaces for Collaborative Design-in-Action

When designers collaborate, many different resources are used to negotiate common ground. Larsson [2] highlights three of these resources as particularly important to a design team's sense making process, all of which can be enhanced or hampered by the workspace design:

- Vocabularies of design – Design teams, global in particular, need to negotiate a shared understanding despite varying language proficiencies, as well as to negotiate

an understanding between people from different cultural, educational and professional backgrounds. The designers use verbal language to actively shape the context and content of the situation rather than passively transmitting and receiving information with a well-defined meaning within a well-defined setting. Sense making is essentially a collaborative process, where the designers collaboratively build a shared vocabulary by talking about the design, thus creating *"a new language capable of describing aspects of the evolving design"* [13].

- Objects of design – Rather than trying to find common ground through verbal communication alone, this can also be negotiated through the use of equally accessible physical objects to all participants. Harrison & Minneman [14] observed the importance of objects in design communication, since they form part of an available *pool of representations* to the design team. A pen, a chair, a sketch, or a simple sheet of paper can act as *shared objects* constructed through collaboration to promote discussions about thoughts, ideas and alternatives.
- Places of design – Depending on their primary purpose, team spaces are equipped with different equipment, such as whiteboards, flip charts and overhead projectors [15]. When design teams occupy a space over an extended period of time, the writings and sketches on whiteboards and flip charts make up *visible permanent records* [16] of the design team's activities and decisions. Project plans, agendas and 'to-do' lists are often posted in ways that make them visible and easily accessible to anyone at a glance. Kirsh [17] noted that places offer a lot of mechanisms to help individuals and groups coordinate work, distribute tasks and manage the flow of information to, for example, *"recall why they left papers out, why folders are open, why there are certain marks on the whiteboards"* .

Design is fundamentally a social process [12, 18] when teams negotiate meaning with the help of just about anything that might help them communicate their thoughts and ideas. When verbal language is not enough, gestures, sketches, prototypes and all possible types of physical objects are used to visualize and describe what they want to 'say' and what they 'mean'. The spaces they use set both a context and a stage for action, and provide them with a collection of *conversational props* [19] for them to collaboratively create common ground. The challenge of designing workspaces successfully incorporating various resources that design teams use is even more demanding when some of these resources are tied to a single physical location. Creating *shared objects to think with* [2] and increasing the extent to which two distributed workspaces feel like one and the same is an appealing vision given that *"physical objects live in one place"* [20].

## 2.2 Workspaces for Research on Collaborative Design

Milne & Leifer [21] suggest the occurrence of a design activity within an ecosystem, where physical and virtual environments are subsets of an overall design environment that is currently an under-examined part of the design innovation ecosystem. In a recent paper, by Milne & Winograd [22], interactive workspaces are too often proof-of-concept workspaces that are neither robust nor extensible enough for real users who can be studied in realistic working conditions. There exists a fundamental need to support interesting research explorations, while allowing interventions (new methods and tools) in the context of ongoing design activities. This need has spurred an increasing interest in how to instrument design team activity so that researchers can automatically collect data on design teams making use of tools in a design environment.

To study design activity in realistic situations, researchers must develop suitable collection methods, thereby ensuring the recording of the appropriate types and quantities of data and other materials without interfering with ongoing engineering work. Milne [23], who elaborated on this further, identifies three relevant challenges for design research:

- Data collection approaches – In terms of time and effort, data collection and analysis are very costly. A more efficient data collection and analysis would allow for a more thorough analysis of real design activity and also increase the sample sizes for experimental research.
- Fieldwork vs. experimental design studies – While controlled experiments provide a greater opportunity to validate specific results, simulated design tasks need to reflect realistic design conditions as accurately as possible.
- Contemplating distributed design – Geographical distribution of a design team increases the number of individuals and observation sites to be considered by the researcher.

Creating future workspaces for collaborative design involves envisioning these workspaces and creating new concepts, methods and tools. However, to successfully inform the design of such new spaces, improving how we observe and analyze design team activities in both co-located and distributed settings is also needed.

# 3. Methods

To aggressively address the challenges above, a multidisciplinary design team consisting of members with backgrounds ranging from mechanical engineering and computer science to human work science and architecture was assembled. Lighting, sound, and interior designers have occasionally been summoned to the team to further ensure as many relevant aspects as possible are adequately taken care of. Many of these workshops were videotaped, all sketches were scanned and the results from meetings and brainstorming sessions were continuously stored in a designer's logbook to help us keep track of our rationale throughout the project.

The project has been greatly influenced by previous research from both co-located and distributed design teams, carried out within the Polhem Laboratory research program. Collaboration with researchers from Stanford University's Center for Design Research has been invaluable in giving us access to a vast resource of experiences from research on design teams to working closely with them in the context of global, industry-near student projects [1, 2, 3, 4]. Other projects providing useful input to the design of the new studio space include a distributed development project between Hägglunds Drives AB and Conex AB, who are 400 kilometers apart [24], and numerous distributed work sessions within DITRA, an inter-provincial project intended to bring the latest distance-spanning technologies and methods to companies in northern Sweden. Several collaboration studios have been developed within the DITRA framework, involving members of our design team whose experiences have been fed into our design process. Inspirational visits have also been made to, for example, the *Wallenberg Hall* and the *iRoom* at Stanford University, Fraunhofer IPSI, the *iLounge* at the Royal Institute of Technology, and IDEO in Palo Alto. In our own immediate surroundings, we have taken inspiration from the brand-new studio at SVT (the Swedish public service TV broadcaster) in Luleå, and the facilities at the School of Music in Piteå.

The design team has paid meticulous attention to future users of the studio, i.e. design researchers, design students and industrial designers. We have employed techniques from the *Participatory Design* [25] tradition, e.g. 'Future Workshops' and 'Cooperative Prototyping',

to promote active user involvement and mediate the different views and interests of the highly multidisciplinary development team. It has been particularly interesting to engage in *Scenario-Based Design* [26], considered to be a powerful framework in our continuous work to reshape collaborative workspaces to better accommodate user needs.

# 4. Design Rationale: Modes of Use

This section describes the underlying reasons for the different 'modes of use' that the new collaborative environment primarily should allow for. The intention is not to separate these modes in time, frequency or importance – these modes are often concurrent – it is to show design as not only incorporating a space for design teams, but also incorporating a research space, a learning space and a marketing space. The rationale is described in terms of *which* modes the studio shall principally allow for, not *how* this functionality could be achieved in practice. Further, the descriptions are not meant to serve as complete guidelines, but merely intended as brief mission statements to keep our studio design team focused on the key priorities and objectives throughout the design process.

## 4.1 Design-in-Action

The studio allows for 'real' design to happen, in a realistic setting, with student or industrial teams. Users are able to move effortlessly between individual and group work and easily find privacy when needed. Adapting the environment as the needs of the group change is easy, since users can quickly re-arrange the setup of chairs, tables, writing surfaces, storage space, etc. The available technologies are easy to find, user friendly, and allow users to focus on the work activity rather than the tool. The studio is compatible for both co-located and distributed design, and is suitable for a wide range of collaborative sessions, including creative brainstorming and more structured design reviews. The studio promotes social connectedness between co-located and distributed teams.

## 4.2 Research on Designing

The studio allows researchers to observe design-in-action, as it unfolds, without any interruptions or disturbances. It is easy for researchers to carry out ethnographic work in the studio, which allows for different degrees of participation depending on the design activity. The studio is instrumented to allow effortless and comprehensive monitoring and recording of activities. The collected material is easily accessible from inside the studio, but can also be accessed from anywhere in the world where researchers might be located. Design teams wanting to experience distributed design can simulate geographic distance, while researchers can easily observe both spaces simultaneously. The flexible setup of the studio allows researchers to rapidly and seamlessly integrate the new tools and technologies created in the course of their research.

## 4.3 Learning

The studio allows students and faculty to work collaboratively and individually, depending on the needs of each course. Dividing into smaller groups to use the appropriate tools and technologies is simple, as is adapting the space to facilitate larger groups possibly requiring different arrangements of chairs, tables, presentation technologies, writing surfaces, etc. The space easily configures to accommodate various degrees of formality, and inviting and connecting to lecturers, coaches or fellow students who might be participating from another site using technologies for distributed collaboration is unproblematic. In activities within our

research center, the studio enables us to ‘live as we preach’, allowing our partner companies the possibility to continuously experience new research findings in a very tangible form.

### 4.4 Marketing

The studio allows us to market our research results, research center and university with the aim to generate more funding and potential research partners on a local, regional, national and international arena. Visitors receive a unique experience, suited to their different preferences, without the need for extensive preparation of presentation material or space reconfiguration. For demonstration purposes, we can easily switch between presentations of the studio as a space for (1) design-in-action, (2) research on designing and (3) learning.

## 5. Design Rationale: Key Features

With the above modes of use as a guiding framework, several key features have been defined and will be described below. Some of these features map directly to particular modes of use, while others are more general *affordances* to be incorporated into the studio. According to Norman [27], the term affordance refers to the *“perceived and actual properties of the thing, primarily those fundamental properties that determine just how the thing could possibly be used. A chair affords ("is for") support, and, therefore, affords sitting.”* [27, p.9] In the context of the ‘flexibility’ feature below, for example, affordance could mean both how a flexible environment actually enables quick and easy reconfiguration (i.e. it *is* quick and easy in practice) and how it perceptually guides quick and easy reconfiguration (i.e. it *looks* like it will be quick and easy).

### 5.1 Flexibility

> *“Looking at work environments, work is increasingly characterized by a high degree of dynamics, flexibility, and mobility. Initial examples include such new work practices as on-demand and ad hoc formation of teams. Contents and participants as well as contexts, tasks, processes, and structures of collaboration will change frequently to cope with the increasing rate of innovation.”* [6, p.37]

There is a great need for flexibility in terms of reconfiguring the workspace size and general arrangement of walls, tables, chairs, etc., to better suit rapid alterations between smaller and larger groups. The space should also be flexible enough to support the temporal range of design activities, e.g. when people work at intervals or when the team moves from one design activity to another, and then iterates it again. Flexibility is basically viewed as the user’s capability to adapt the surrounding environment to new, different or changing needs, but since the user can be a designer, a researcher or a learner, the notion of flexibility spans several modes of use, in both co-located and distributed settings. Below are a few of the modes that require flexibility.

- Co-located design-in-action
- Distributed design-in-action
- Co-located research on designing
- Distributed research on designing
- Co-located learning
- Distributed learning

## 5.2 Social Connectedness

Cohen & Prusak [28] recognizes the need for *"places to gather, to meet, to talk, to see and be seen"* and further suggest that organizations would be wise to invest in both social space and social time if they want to build social capital.

> *"Social capital consists of the stock of active connections among people: the trust, mutual understanding, and shared values and behaviors that bind the members of human networks and communities and make cooperative action possible."* [28, p.4]

Social interaction is critical in creating a shared understanding and a willingness and motivation to share information, knowledge, and expertise. However, distributed engineering design teams face a serious problem of 'disconnectedness', since their access to knowledge and expertise is highly impeded by the social, geographical and temporal distribution of these resources [29]. The studio needs to promote interpersonal and social contact, in varying degrees of formality and spontaneity, as well as address the above challenge of achieving social connectedness across distance.

Below are a few examples of social interaction that needs to be supported.

- Opportunistic communication – Conversations anticipated by one party, but occurring by chance [30].
- Spontaneous communication – Conversations unanticipated by either party [30].
- Presence & awareness – What is experienced through the informal, everyday interactions between people who work in the same physical space – a general sense of who is around and what they are doing [31].
- Communal eating – Eating together is a way of deepening social bonds, with communal eating being one of Alexander's living patterns [11, p.696]. Nardi and Whittaker [32] note, *"Eating and drinking together perhaps comprise the most fundamental way in which people come to feel connected."*

## 5.3 Simulating Geographic Distance

From an educational perspective, we want our students to gain experience from working in distributed design teams. From a research perspective, being able to simulate a distributed design setting within the new environment is very appealing. This enables us to replicate and observe a 'remote' team, while retaining the capability to observe the 'local' team, something that is not possible to do without traveling to the remote site. Altogether, it is crucial to find low-cost, low-effort alternatives to set 'real' distributed design projects that can be experienced by students and observed by researchers. This allows us to rapidly implement and evaluate new methods and technologies to be deployed in real-world global collaboration settings with partners from academia and industry.

## 5.4 Individual vs. Group Work

In future workspaces, the problems of moving efficiently between individual and group work need to be addressed. We need to find ways to seamlessly and quickly transition from, for example, privately writing on a report for a management meeting to publicly annotating a presentation slide in collaboration with co-located or remote colleagues. Designers and learners need to sometimes break out as individuals or sub-groups, while still being aware of the happenings in a larger group context. Their active participation in a group session is

sometimes needed, though still being able to attend to various individual work issues. Below are two examples of features that we would like to support in this regard.

- Privacy – Fundamentally, people should not have to leave the studio to receive some privacy. People must be provided with the appropriate level of privacy to work effectively and productively while not being isolated from the group, which involves dealing with acoustical, visual, territorial and informational privacy.
- Side conversations in distributed design – The opportunity to partake in private conversations within a public discussion is reserved only for people in the same physical location. Side conversations provide opportunities to explore vague ideas and alternative paths in a quick, informal and iterative manner [4]. The possibility to engage in group communication over long distances using simultaneous conversational floors is an interesting research challenge.

## 5.5 Unremarkable Technology

Weiser's [33] vision of *ubiquitous computing* included hiding the 'dramatic' features of technology to become an embedded and natural part of, in our case, the studio design. Fundamentally, technology and information should be present in the periphery until needed, and should simply fade into the background again when not in use. Tandler et al [6] distinguish between *physical disappearance*, mainly due to the miniaturization of computer parts and their integration in other artifacts, and the *mental disappearance*, achieved when computers become 'invisible' to the user's mental eye and thus to human perception. We aim to extend the possibilities to achieve 'invisibility in use' so that the technology is altogether unremarkable and natural, while it might in fact be perceptually visible.

## 5.6 Memory Space

It is important to address issues of space ownership and the possibility for teams to leave work-in-progress in a space they might be sharing with other teams. People working at intervals need to be certain of the persistence of their work, meaning that the objects (whiteboard sketches, post-it notes, mock-ups, etc.) left in the space remain for an appropriate amount of time. This challenge of providing suitable memory space includes the persistence of both physical and digital objects produced during a project.

> *"Whether they store information on a low-tech whiteboard or a high-tech flat screen, continuous access to the visual display of information helps everyone get back up to speed quickly when the group reconvenes. Supporting visual memory with information persistence augments communication, learning, decision making and problem solving."* [34]

## 5.7 Identity, Culture and Symbolism

It must be stated that this is not just another collaborative workspace; it is a physical manifestation of the culture of innovation that we promote. We believe in investing in productive workspaces that 'celebrate' teamwork. The identity is more than just a name and a logotype, which is why we have not yet decided on these details, but the identity the physical space reveals is more important, both in terms of what is visible at first sight and in terms of what users will experience on site. We want the space to communicate our view of collaboration as a central concept, and leave an immediate impression as a highly reconfigurable, renewable, changeable and flexible space that will allow its users (researchers, design teams, teachers and learners) to easily adapt it to their needs. Taking the notion of a

space for social connectedness as an example, it is not about allocating social interaction to one single space – rather it is a way of making a statement, a way of signaling that social connectedness is so vital to successful collaboration, we have even created a symbolic space where new concepts of socialization can be explored.

> *"…companies that want to break away from the pack can take a big step toward doing so by thinking of their physical environment as not only a place where works get done, but also a place that sends a message."* [35]

## 6. Design Concepts: 1st Generation

The design process has largely been inspired by the guiding design principle – *"build the best socket we can afford"* [36] – offered by Professor Larry Leifer for the development of the Wallenberg Hall at Stanford University. He responded to the need of developing an infrastructure capable of supporting whatever technology develops over the lifetime of the building, i.e. we have never intended to create a 'final' solution to the features and modes described in previous sections. The design rationale described in section 5 attempts to scope, or frame, the fundamental aspects we believe influence the development of highly versatile collaborative environments. The rationale presents numerous significant research challenges, none of which are considered trivial to address. In fact, the entire motivation for creating this studio has been to create a space where these challenges can be adequately addressed. In the next section, a selection of first generation design concepts is highlighted, attending to the key features presented in section 5. It is not intended as a complete list of detailed designs, but rather as an initial set of design proposals or 'directions' to help us put the desired features into practice. These and forthcoming concepts, will be subject to continuous improvement. Figure 1 shows design sketches of some of the concepts.

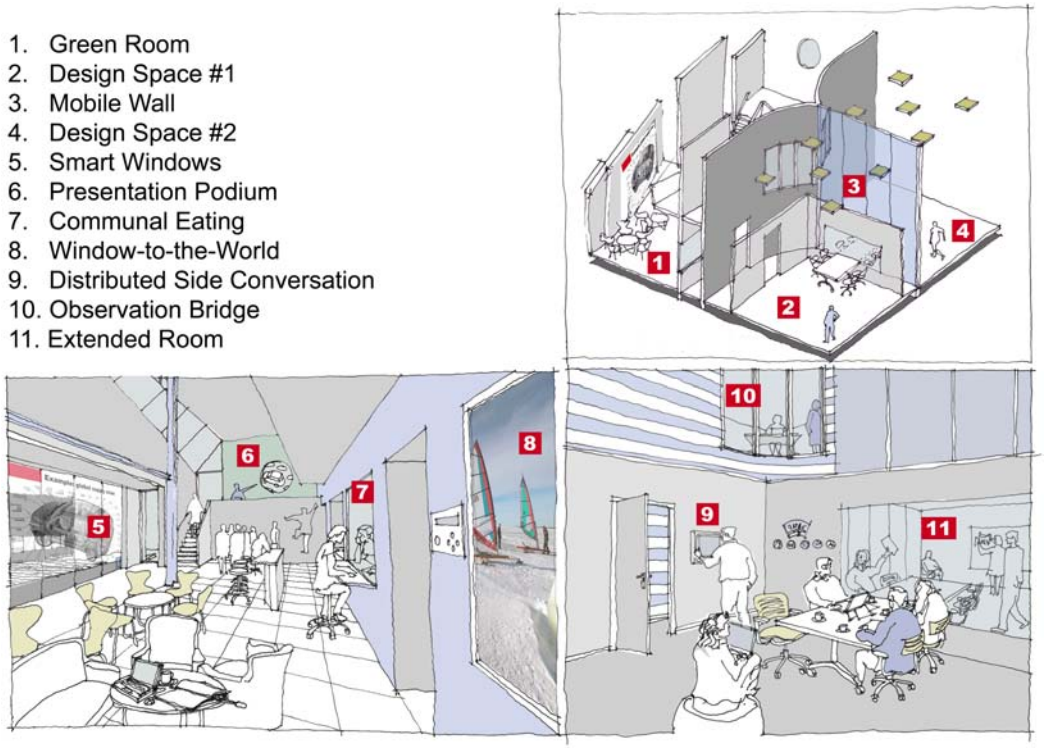


Figure 1. Concept Design Sketches, courtesy of Hans Walloschke, Arkitekthuset Monarken.

**User flexibility** – Part of the flexibility in the two design spaces (see Figure 1, numbers 2 and 4), is created by using chairs and tables on wheels, making them easy to move around for different types of individual or group settings. By using folding tables and nesting chairs, we enable users to quickly free more space if and when they need it. Lightweight boards are fitted with different surfaces on each side to achieve reversible, multi-purpose whiteboards and bulletin boards. These boards can be set up virtually anywhere in the studio thanks to a concealed hanging system. Power and data distribution hubs are placed under the raised floor, with quick and easy access. A wireless network covering the complete studio environment ensures users can stay connected at all times, from anywhere within the studio. User flexibility also includes effortless modifications to the lighting and sound environment, achieved from both portable interaction devices and any computer connected to the network.

**Researcher flexibility** – Researchers need flexibility in terms of setting up the environment to fit a specific scenario or evaluating different types of environments, methods or technologies. Here, the researcher's role is similar to that of a director; he/she sets up the stage and decides what the environment should look like to fit the scenario or the 'real-world' design activity in question. Depending on the required setup in each scenario, this type of flexibility will require more time than in the case of the users. The two design spaces (see Figure 1, numbers 2 and 4) are actually part of one large room divisible into two separate spaces with a moveable sound-proof wall. Inside these spaces the 'design office' is constructed in the form of stage sets - modular walls that can be connected to create one consistent environment. By using interchangeable stage sets or modules equipped with different types of projection devices, interaction devices and lighting, a specific environment can be rapidly designed. Equipped with lighting trusses, these two spaces accommodate a flexible lighting design. A raised floor is used to encase all wiring, including the power and data distribution hubs users need to access.

**Social connectedness** – Keeping with the theatre analogy, we have created a *Green Room* (i.e. an off-stage area where actors 'hang out'). With three permanent walls, this space (see Figure 1, number 1) is less flexible than team spaces, though the wall between the Green Room and the team spaces is modular to accommodate different types of technologies, such as back screen projection units. This space offers a cozy living-room feel with comfortable sofas and chairs and has a bar area equipped with distance-spanning technologies to enable communal eating and drinking with remote partners. Technology is hidden as much as possible to achieve a 'calm' ambience, and display screens double as fish tanks, fireplaces or windows-to-the-world when not used for other purposes. One example of such technology is the electro-chromic glass (see Figure 1, number 5) used to achieve the 'smart windows' in the Green Room. By flicking a switch we can vary the transparency of the windows, allowing us to use the windows as large projection surface if the need should arise.

**Simulating Geographic Distance** – By using a movable and sound-proof wall to divide the large team space (see Figure 1, number 3), two smaller studios can be created to simulate geographic distance, enabling the researcher to simultaneously visually observe the two groups from the elevated 'observation bridge' while staying in complete control over the technical environment at both sides.

**Individual vs. Group Work** – A private communication area will enable side conversations in distributed collaboration (see Figure 1, number 9). Participants wanting to engage in a side conversation simply move to the side conversation area where they communicate without interrupting the others, while still overhearing the large meeting. To facilitate effortless moves between individual and collaborative work, users will have the ability to create semi-private spaces via the use of storable, retractable privacy screens. Retractable room dividers able to be reconfigured into various convex and concave shapes to encourage different types of work

offer another interesting concept. For example, the convex side would promote individual work by pushing people apart, while the concave side would promote collaborative work by bringing people together.

**Unremarkable Technology** – In the design of the new studio much effort has gone into integrating technology into the architecture (i.e. displays and interaction devices are integrated into the walls). One example of unremarkable technology is an interactive window, i.e. plasma screens fitted with window framing and integrated into the modular walls (see Figure 1, number 8). Displaying a nice picture or view from a remote camera fulfills the illusion of a window-to-the-world. This 'window' can also be used as a normal display area for notes, conferencing or computer graphics.

**Memory Space** – To enable a memory space for several teams that may share the same physical space, some *information persistence* is required. This basically means that the information can remain essentially unchanged between sessions. If the team works with virtual objects, such as CAD drawings, a session management system makes it possible to recall previous work sessions. Persistence when interacting with physical artifacts is more cumbersome, but by using portable and lightweight whiteboards and storage compartments on wheels, these artifacts can at least be stored locally between sessions.

**Identity, Culture and Symbolism** – In a distributed meeting, culture and identity are even more central; therefore, clearly visualizing the identity of a remote space can further enhance the collaborative feeling of being a distributed team. A backdrop of a local landmark enhances the feeling of collaborating with people in one specific place and not just with people in an anonymous studio located in the next building. By changing the identity in both remote collaborative spaces to the same theme, an extended room can be created where the local space 'reaches out' into the remote studio and promotes a feeling of working together as one team in the same room. The aim has also been to reflect elements of the culture of northern Sweden (northern lights, midsummer night sun, ice, snow etc.), while the environment associates visitors and users to the future of work instead of how they work today or have worked in the past.

# 7. Conclusion

The collaborative workspace described in this paper responds to the increasing demands globalization has placed on design teams working in industry by offering an environment for research, education, and practice. Here, design activities can be monitored and observed by researchers, and the technological and physical setup of the studio can be rapidly re-arranged to fit the needs of the workspace users. The studio provides an opportunity to observe both co-located and distributed design teams in action, and to automatically collect data on the use of the workspaces. The possibility to simulate geographic distribution in an "extended room" fashion is likely to greatly impact engineering education, since it allows for design students to experience at least some of the opportunities and challenges of working in a distributed team. The versatility of the studio allows for endless possibilities to rapidly implement and evaluate emerging technologies, tools, and workspace concepts.

The studio will be physical proof of our research group's intention to continually improve the opportunities for successful collaboration in global design teams. It is also evidence of our outlook on collaborative design as a highly complex process, including a multitude of social, technical, and cultural activities that we as researchers need to closely observe for a better understanding. Further, the studio embodies our belief that students must experience distributed collaboration first-hand to excel at it, with versatility being a key aspect of such

modern design collaboration. Industry team workspaces are used by many different groups of users, with different demands and work methods; hence, the ability to quickly adapt a workspace to the situation is critical to the performance of the team. Rapid transitions between co-located and distributed work, individual and group work, and listening and acting require that the supporting tools and technologies as well as the surrounding physical environment offer the capability to support creative teamwork without disruption.

Our intention has been to create a rapid-response environment, where we can evaluate the significance of issues raised through ethnographic observations of engineering work and then offer solutions to these relevant issues. The new studio can thus be seen as a reification of our iterative research approach, where the basic methodological argument is as follows:

1. *Scoping ethnography* [37] is carried out to identify issues that appear to be relevant to the design of collaborative environments, methods and technologies.
2. The *actual* significance of these issues is evaluated in the studio, which acts as a test-bed for both 'real-world' development projects and *Scenario-Based Design* [26] activities.
3. Proposed solutions to *significant* issues are rapidly implemented, after which the research cycle is iterated in a continuous process of scoping, evaluation and implementation.

Future work includes further exploration of concepts to meet the needs and rationale described in this paper. The inauguration is planned by early spring 2006.

**References**


[1] Larsson, A., Törlind, P., Karlsson, L., Mabogunje, A., Leifer, L., Larsson, T. and Elfström, B-O. "Distributed Team Innovation: A Framework for Distributed Product Development", International Conference on Engineering Design (ICED'03), Stockholm, Sweden, 2003.

[2] Larsson, A. "Making Sense of Collaboration: The Challenge of Thinking Together in Global Design Teams", International ACM SIGGROUP Conference on Supporting Group Work (GROUP'03), Sanibel Island, FL, USA, 2003.

[3] Törlind P. and Larsson A. "Supporting Informal Communication in Distributed Engineering Design Teams", Annals of 2002 International CIRP Design Seminar, Hong Kong, 2002.

[4] Larsson, A., Törlind, P., Mabogunje, A. and Milne, A. "Distributed Design Teams: Embedded One-on-One Conversations in One-to-Many", Common Ground: Proceedings of the Design Research Society International Conference, Brunel University, UK, 2002, pp.604-614.

[5] Byrne, J. "The Virtual Corporation", Business Week, Feb 8, 1993, pp.98-104.

[6] Tandler, P., Streitz, N.A. and Prante, T. "Roomware – Moving Toward Ubiquitous Computers", IEEE Micro, Nov/Dec, 2002. pp.36-47.

[7] Fox, A., Johanson, B., Hanrahan, P. and Winograd, T. "Integrating Information Appliances into an Interactive Workspace", IEEE Computer Graphics & Applications, 20 (3), May/June 2000.

[8] Chen, W., Towels H., Nyland, L., Welch G., and Fuchs, H. "Toward a Compelling Sensation of Telepresence: Demonstrating a Portal to a Distant (Static) Office", Proceedings of the IEEE Visualization 2000, Salt Lake City, UT, USA, 2000.

[9] Fernando, T. et al. ”Future Workspaces - A Strategic Roadmap for Defining Distributed Engineering Workspaces of the Future”, IST-2001-38346, 2003. Accessed March 18 2005, www.avprc.ac.uk/fws/

[10] Harrison, S. and Dourish, P. ”Re-Place-ing Space: The Roles of Place and Space in Collaborative Systems”, In Proceedings of CSCW’96, Cambridge, MA, USA, 1996.

[11] Alexander, C. et al. 1977. ”A Pattern Language: Towns, Buildings, Construction”, Oxford University Press, New York, NY, USA, 1977.

[12] Minneman, S.L. ”The Social Construction of a Technical Reality: Empirical Studies of Group Engineering Design Practice”, Ph.D. Dissertation, Department of Mechanical Engineering Stanford University, CA, USA, 1991.

[13] Lloyd, P. ”Storytelling and the Development of Discourse in the Engineering Design Process”, Design Studies, 21 (4), 2000, pp.357-374.

[14] Harrison, S. and Minneman, S. ”A Bike in Hand: A Study of 3-D Objects in Design”, In Cross, N., Christiaans, H. and Dorst, K. (Eds.), Analyzing Design Activity, Wiley, New York, NY, USA, 1996, pp.417-436.

[15] Roseman, M. and Greenberg, S. ”TeamRooms: Network Places for Collaboration”, In Proceedings of CSCW’96, Boston, MA, USA, ACM Press, 1996, pp.325-333.

[16] Teasley, S.D., Covi, L., Krishnan, M.S. and Olson, J.S. ”How Does Radical Collocation Help a Team Succeed?”, In Proceedings of CSCW’00, Philadelphia, PA, USA, ACM Press, 2000, pp.339-346.

[17] Kirsh, D. ”The Context of Work”, Human Computer Interactions, 16 (2-4), 2001, pp.305-322.

[18] Bucciarelli, L. L. ”Designing Engineers”, MIT Press, Cambridge, MA, USA, 1994.

[19] Brinck, T. and Gomez, L.M. ”A Collaborative Medium for the Support of Conversational Props”, In Proceedings of CSCW'92, Toronto, Canada, ACM Press, 1992.

[20] Everitt, K. M., Klemmer, S. R., Lee, R. and Landay, J. A. ”Two Worlds Apart: Bridging the Gap Between Physical and Virtual Media for Distributed Design Collaboration”, In Proceedings of CHI’03, Ft. Lauderdale, FL, USA, ACM Press, 2003.

[21] Milne, A. and Leifer, L. ”The Ecology of Innovation in Engineering Design”, International Conference on Engineering Design (ICED’99), Munich, Germany, 1999.

[22] Milne, A. and Winograd, T. ”The iLoft Project: A Technologically Advanced Collaborative Design Workspace as Research Instrument”, International Conference on Engineering Design (ICED’03), Stockholm, Sweden, 2003.

[23] Milne, A. ”An Information-Theoretic Approach to the Study of Ubiquitous Computing Workspaces Supporting Geographically Distributed Engineering Design Teams as Group Users”, Ph.D. Dissertation, Department of Mechanical Engineering, Stanford University, CA, USA, 2005.

[24] Törlind, P. ”Distributed Engineering via Broadband –A Case Study”, International Conference on Engineering Design (ICED'03), Stockholm, Sweden, 2003.

[25] Schuler D. and Namioka A. (Eds.). “Participatory Design”, Lawrence Erlbaum, Hillsdale, NJ, USA, 1993.

[26] Carroll, J. (Ed.). ”Scenario-Based Design: Envisioning Work and Technology in System Development”, Wiley and Sons, New York, NY, USA, 1995.

[27] Norman, D. A. ”The Design of Everyday Things”, Doubleday, New York, NY, USA, 1990.

[28] Cohen, D. and Prusak, L. ”In Good Company: How Social Capital Makes Organizations Work”, Harvard Business School Press, Boston, MA, USA, 2001.

[29] Randall, D., O’Brien, J., Rouncefield, M. and Hughes, J.A. ”Organisational Memory and CSCW: Supporting the ‘Mavis Phenomenon’“, Proceedings of OzCHI 1996, Hamilton, New Zealand, 1996.

[30] Kraut, R.E., Fish, R.S., Root, R.W., and Chalfonte, B.L. ”Informal Communication in Organizations: Form, Function, and Technology”, In Baecker, R.M., Readings in Groupware and Computer-Supported Cooperative Work: Assisting Human-Human Collaboration, Morgan Kaufman Publishers, San Mateo, CA, USA, 1993.

[31] Greenberg, S. ”Peepholes: Low Cost Awareness of One's Community”, In Gutwin, C., Greenberg, S., and Roseman, R., Supporting Awareness of Others in Groupware, A short paper suite, ACM SIGCHI'96 Conference on Human Factors in Computing System, 1996, pp.206-207.

[32] Nardi, B. and Whittaker, S. ”The Place of Face to Face Communication in Distributed Work”, In Distributed Work: New Research on Working across Distance Using Technology, Hinds, P. and Kiesler, S. (Eds.), MIT Press, Cambridge, MA, USA, 2002.

[33] Weiser, M. ”Creating the Invisible Interface”, Invited talk, In Proceedings of the ACM Symposium on User Interface Software and Technology, Marina del Rey, CA, USA, 1994.

[34] Steelcase, Inc. ”Face to Face, Screen to Screen: Collaboration in the New Workplace”, Face-to-face, Workplace Issues: One in a Series, www.steelcase.com, Accessed March 18 2005.

[35] Herman Miller, Inc. ”Three-Dimensional Branding”, www.hermanmiller.com, Accessed March 18 2005.

[36] Gilbert, D. ”Designing More than a Room”, Presentation at National Learning Infrastructure Initiative (NLII) Learning Space Design Focus Session, Cambridge, MA, 2004, Accessed March 18 2005, http://scil.stanford.edu/about/staff/bios/PDF/NLII_Fall04_DMG.pdf.

[37] Randall, D., Harper, R. and Rouncefield, M. ”Fieldwork for Design”, Kluwer Academic Press, Amsterdam, Netherlands, forthcoming.

**Acknowledgements**

The financial support from the Kempe Foundations and the Knut and Alice Wallenberg Foundation is greatly appreciated. Special thanks are also due to Anne Balsamo, Scott Minneman, Dave Randall, Hans Walloschke, Sture Berglund and Bernt Viklund.

Andreas Larsson, Polhem Laboratory, Division of Computer Aided Design, Luleå University of Technology, SE-971 87 Luleå, Sweden, Tel: +46 920 491874, Fax: +46 920 99692, E-mail: Andreas.C.Larsson@ltu.se, URL: http://www.cad.ltu.se/.