Opening the Digital Box for Design Work: Supporting Performative Interactions, Using Inspirational Materials and Configuring of Place

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1 Introduction

1.1 Configurable Ubiquitous Technologies and Media

We started the work reported on here with the ambition to create inspirational learning environments for design and architecture students in the spirit of Weiser's vision of taking the computer "out of the box" and making computational resources augment a design studio environment ubiquitously. Computing environments are becoming populated by a rich and diverse set of devices and networks, many of them integrated with the physical landscape of space and artefacts. Early attempts to take the desktop metaphor of graphical interface design back to the real desktops and whiteboards by exploring new semantics of interaction was pioneered by Weiser's group, as well as by Buxton and others (Weiser 1993; Fitzmaurice 1995; Rekimoto 1997). The idea to have a new and more complex set of physical handles to digital media promised a richer interaction between people and technology, and, in line with Engelbart's pioneering work on direct manipulation for graphical user interfaces (Engelbart 1962), a new set of generic interface building blocks would open up a new realm for design of interaction technologies.

In parallel to the work of Weiser, Wellner and colleagues argued for a new and broader interpretation of augmented reality turning computational augmentation into an enhancement of practices well established with the interaction of more mundane artefacts (Wellner 1993). Fuelled by ethnographic studies of work, researchers such as Mackay et al suggested augmented environments where computational resources were brought into play, as extensions of for example the paper flight strips traffic controllers used to control airplanes as they passed through different traffic sectors (Mackay 1998) Such an approach is not in opposition to the development of new interaction modalities but it shifts the balance from a generic interaction scheme to the situated embodiment of interactional possibilities. Ishii and his group forged these two approaches into a wider program for tangible interaction (Ishii 1997). With the ambition

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to create seamless interfaces between "people, bits and atoms", Ishii and others have expanded the new field of design to include an integrated re-shaping of desks, board and rooms.

The growing number of experimental ubicom installations has helped shift the focus of interactive systems away from individual work settings and towards larger collaborative environments traditionally the realm of other designers. After some years where automatically generated context information created high hopes for how computational technologies could be made to match the complexity of user behavior (Salber et al. 1999). We are increasingly seeing suggestions for open infrastructures and end-user configurable systems, which may have a lower intensity of computational monitoring, but on the other hand appear more easily extendable to wide spread real life settings. However many of these approaches are technology driven rather than being driven by a concrete practice or setting (Kindberg et al. 2002; Newman et al. 2002). This new type of extendable systems with open boundaries could provide traditional human computer interaction research with important new challenges (Belotti et al. 1992; Grudin 2002). This view is closely related to our experiences within the *Atelier* project and the architectures and technologies in support of inspirational learning that we have explored. The *Atelier* project has been exploring inspirational forms of learning and how to build augmented environments in support of design education. The experiences are related to the general field of ubiquitous and tangible computing and especially to ideas of embodied interaction as a new stance for understanding of both, social and physical, interaction with artefacts and space. It is suggested that concepts like "configuration of mixed objects" and "appropriation of mixed places" together form interesting challenges for the design of architecture and technology for inspirational learning environments.

1.2 Research Approach: Pro-Searching Practice

The two practice settings of inspirational learning environments that formed the basis for observation, design and evaluation were chosen to be complementary. One was a "traditional" master-class environment in architecture in Vienna. It was complemented and contrasted by the setting of a new-media-oriented, interaction design, master program in Malmö.

The approach taken could be seen as design oriented research (Fällman 2003). We have studied design education practice, developed prototypes to enhance such education, introduced prototypes to different real use settings (design and architecture master-classes), hence encountering unintended or unexpected appropriation by the students, and, partly in collaboration with the students, reflected upon the interventions to learn both about how to improve architecture and technology and the learning situation. The idea has not primarily been to examine the past for generalisations or continuous trends, but to generate knowledge by pro-searching (scouting, trailblazing) the present for possible new ways and desirable futures. This pro-searching, as Klaus Krippendorf (Krippendorf 1995) has called this process, is built upon a user-collaborative approach involving users and researchers as reflective co-designers and evolves from early exploring of practice and visions through experiments with gradually more integrated scenarios and prototypes for inspirational learning.

Iteration is a significant aspect of these interventions and reflections. An iterative research and design process for refinement of architecture and technology for inspirational learning environments went through three design cycles: envisioning, prototyping and experiencing. Each design cycle was based on interventions into the everyday practice at two design education sites. The first design cycle was oriented towards ethnographic observations in existing classes, combined with inspiration from art practice, leading to scenarios of enhanced inspirational learning environments and observations of qualities of such environments. The interventions in the second design cycle were stronger: Students were confronted not only with scenarios, technology prototypes and architectural elements, but also with project assignments inviting them to explore ideas and technology for augmenting their design learning environments. The students' appropriation and evaluation of the ideas and the technologies led into the design of more integrated, but also new, technological and architectural components, for the final round of design interventions, again with changed curricula. Experience from this last round of interventions, again led to new technologies for augmenting design learning environments.

"Concurrent design" and "cross-dressing" are other important factors improving the quality of interventions and sensibilities to outcomes. We took the unusual approach of "concurrent" development of technological infrastructure and components, with conceptual development of architecture and technology for inspirational learning environments, and investigations of design practice for architecture and interaction design students. This "concurrent" process was coordinated via workshops in the beginning, middle and end of each design cycle aligning the different actors' activities. There was an important element of "cross-dressing" between interventions and observations from the architecture classes with a stronger focus on materials and space and the interaction design classes more focused on exploring interaction and digital media. The combination of early probings with technology, rapid and flexible development of technological infrastructure and successive hard-edged integrative development efforts resulting in working demonstrators, has managed to stay closely connected with the overall framework of concurrent concept development and participatory pro-searching of practice. In addition to reflections on students' appropriation of architecture and technology for inspirational learning, exhibitions of demonstrators and workshops around central ideas with professional participants outside the student design setting have been important for the assessment of quality of concepts and technologies.

As a result of the initial field trials the project identified particular "atmospheric", material and spatial qualities that should be created and supported. These qualities were: the transient and ephemeral, materiality and the diversity of materials and representations, creative density, re-programming and the "different view", experience of dimensionality and scale, performative interaction, forging connections/multiple travels, configuring, tempo and rhythm. These qualities acted as powerful guidelines throughout the project, for technology design, for developing notions of use, for setting up field trials at the two sites, and for interpreting our observations (see section 2).

1.3 Context: Design Education and Inspirational Learning

The environment for exploring support of design education was the Academy of Fine Arts in Vienna and the school of Arts and Communication at Malmö University. The

Academy of Fine Arts has a history reaching back to 1692. The education of architects at the Academy is based on "project oriented studies". The traditional studio-like learning environment is the place where a diversity of resources - disciplines, people, materials, technologies - are brought together. These resources are multi-medial - their instantiations range from physical objects like CAD plans, sketches and scale models to samples, product catalogues, art books, and everyday objects, as well as immaterial resources such as conversations and emotions. The School of Arts and Communication at Malmö University is on the contrary very young admitting its first students in 1998. A broad perspective on the interaction design field is applied. Interaction design is a multi-disciplinary subject and students have a mixed background including computer science, design, art and music. Besides the computer, they typically work with a mixture of video clips, mock-ups and other physical representations, scale models, prototypes, etc. Our notion of learning in these two environments was strengthened in our first round of field trials, where we carried out ethnographic studies of students' work practice, including the use of cultural probes (Gaver et al. 1999).

- Learning in these environments is stimulated by the presence of inspirational resources – images, music, metaphors, atmospheres, film, samples of materials, and everyday objects, which provide an element of surprise and discovery and help see things differently.
- Learning proceeds by students working with design representations in different media, gradually transforming them into a design in a process which is non-linear, informal, and highly cooperative. The diversity of material and media is an important facilitator of learning. Students work with and produce text, diagrams, comics, video, sketches, sketch models, screenshots, virtual models, and prototypes – material of different degrees of abstraction, different scale and materiality.
- Learning is highly interactive. Students constantly switch between individual and collaborative work. They share knowledge and design material, use collective displays, take turns in working on a specific task to then arrange a spontaneous meeting. While switching mode and tasks, they circulate the space, expanding and concentrating it according to their needs.
- People, co-present and distant, are a crucial part of an inspirational learning environment. Students receive regular feedback from peers, their teachers, and external reviewers, they listen to guest lectures and they meet people when they are cruising the outside world, exploring the city, a particular context or site. There is the need to bring the impressions and the material they collected back to the studio, to make it visible and share it with others.

1.4 Qualities in Action and Emerging Concepts: Opening the Digital Box for Design Education

In the field trials we explored approaches to mixing physical and digital artefacts, experimented with ways of integrating the physical space into the students' learning activities, and investigated the possibilities of configuring the environment. The strategy for these field trials was not to create new and dedicated artefacts and spaces but to motivate students to integrate the prototypes into ongoing project work.

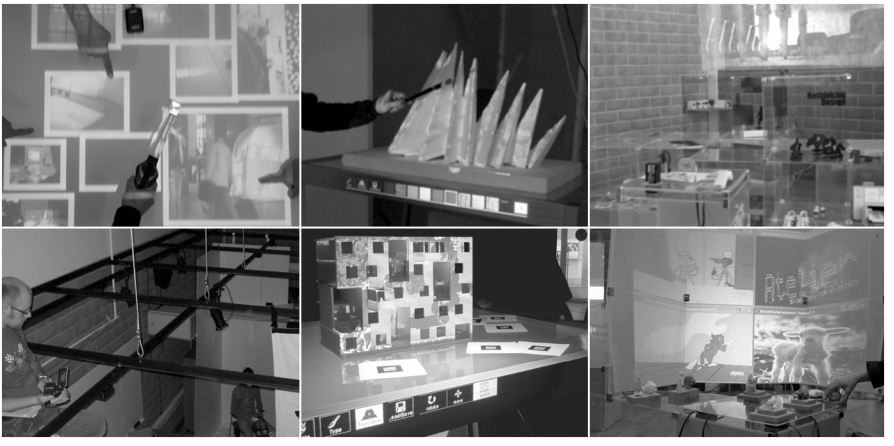

Fig. 1. From top left to bottom right; The Tracking Game Table, The Texture Painter, The Tangible Archive, The Interactive Stage, The Mixed Objects Table and The Physical Building Blocks

This was enabled by what we see as the "open-ended" nature of the prototypes. The major such "open-ended" prototypes or demonstrators included:

- The Tracking Game Table allowing manipulaton of projected frames in which images and videos are displayed
- The Texture Painter for "painting" computer generated visual overlays as texture on physical models using a physical-digital brush
- The Tangible Archive and organizing zone as a place for informal storing, combining and presenting mixed materials,
- The Interactive Stage combining element of a theatrical space with technological augmentation to manipulate media and events,
- The Mixed Object Table including The Texture Painter and other tools and interaction modes for visual overlays on and around physical models
- The Physical Building Blocks for illustrating ideas and concepts in very concrete, interactive full-scale mock-ups and prototypes.

The components of these demonstrators were intergrated via a shared, platform independent, infrastructure and a hypermedia database. In general findings of the research focus on:

- *inspiration* as residing in the diversity of design materials on the one hand, and in the movement of connecting and performing multiple travels on the other hand,
- design work as a process of *transforming design representations* and the role of *mixed objects,*

- the role of *performative interactions* for design work, in particular how spatial features participate in the configuration of mixed media environments and the performative aspects of how people interact in them,
- the importance of supporting students in *configuring* their learning environment of artefacts, technologies and space.

In the later sections we will reflect upon these experiences and emerging concepts, particularly in designing architecture and technology for inspirational learning. In the next section this will be done with a focus on "design qualities in action" and how design practice has been enhanced. The perspective is further broaden into more general conceptual reflections on "performative interaction", "mixed objects", and "configuring of place".

2 Enhanced Design Practice – Qualities in Action

In this section we will conceptually articulate and illustrate some of the explored design qualities in action and their importance for an enhanced design practice: design work as transforming representations, performative interaction, configuring, creative density and multiple travels.

2.1 Design Work as Transforming Representations

An important finding early in the project, as a result of the field trials, was the definition of "diversity of representations" as central to design work at both sites. The phrasing was inspired by Bruno Latour's use of the concept of circulating references to describe how matter gradually moves along a chain before eventually ending up as knowledge (Latour 1999). The references circulate along a series of representational transformations by use of scientific methods and instruments. In that way a sample of soil from the jungle gradually is transformed into formal knowledge representations such as diagrams. The term could well be used to describe how ideas are transformed throughout the design process.

It is a challenge for the designer to handle a multitude of different media and representations. The transference from one media to another without loosing essential qualities is often a crucial issue. Transforming and configuring the design material is in some sense the major part of design work. Clarifying ideas in a sketch in order to explain to others, making a model or enacting with a mock-up are all examples of moving between representations. Experiencing the material from different perspectives or in different scale is important for gaining an open design space where ideas can be stretched in any direction before narrowing down in realization. This means that embodiment or working in full scale is but part of representation and experience, there is no ideal format. The environment must support moving from abstraction to concreteness and we have tried to afford that by including space in design and by letting it be inhabited by mixed objects.

Students' project work proceeds through developing a large number of design representations. These are characterized by the expressive use of a diversity of materials and are sometimes animated and presented dynamically. As an example two students

worked on a façade for a furniture house, who sponsored a student project, for their main inner city building. The students envisioned the façade of the building as a threshold between inside and outside. On their table are sketches of the form of the façade, detailed plans, drawings visualizing atmospheres and situations of use, 3D models, diagrams - a collage of visual and tactile material. One reason for this diversity of representations is that changing media and scale adds to the quality of the design process, with different techniques allowing to explore different aspects of the design idea. These heterogeneous representations are often manipulated simultaneously and they evolve in different versions. We can say that design work is creating and manipulating a multiplicity of design representations, jumping between modalities, scales, and materials, thereby transforming them.

These observations convinced us of the need to maintain the diversity of representations and to help students to enhance the representational techniques that are part of their professional practice, providing them with barcodes and scanners, RFID tags, and touch sensors. In the first round of field trials they used these technologies mainly for animating design artefacts through connecting them with multi-media files.

A special aspect of design work as transforming representations is what we called "re-programming". Part of the students" training consists in learning "to see things differently". This implies changing (strangely) familiar images - altering the city, the landscape, objects of everyday life. Students are encouraged to collect and mobilize inspirational material – which is to do with particular qualities of objects, people, ambience, a place – as this plays an important role in seeing things differently. They may vary the context of an object through simple projections, e.g. place a railway station in the midst of a jungle or igloos in the desert (without having to do complex renderings). They may play with dimensionality, scaling up and scaling down, changing familiar objects and thereby arriving at unexpected uses. They may use visual effects for seeing things differently, such as "fuzziness" – views that blur, distort, veil and allow things to remain ill-defined, unfocused and indistinct.

One example observed was how the *Texture painter* (Figure 2) was used by students for performing their models at the final project presentations. Another example is how first semester students used it on their 1:50 and 1:20 scale models of famous architectures made from white styrofoam. They applied different kinds of textures to their models, inserted video material, changed the material of some parts of the model in order to achieve special effects, and systematically varied the context of the buildings. This was done in a playful way and helped them explore the possibilities of seeing – interpreting, analysing, criticising - an architectural object. The students captured these changes with a digital camera and it turned out that this double-digital-processing worked out well - a *Texture painter* layer, photographed by a digital camera – "even better than a life paint"?

2.2 Performative Installations

Students create interactive installations to objectify, present, and discuss their design projects. Installations are inherently different from staged performances, as they engage the spectator bodily, allowing them to turn into co-players (Suderburg 2000). This is evident in some of the installations the architectural students produced, such as the "train ride".

The “train ride” installation consists of a movie of a trip to a stadium in Paris, including the *Atelier* studio space in their performance. Seats were arranged like in the underground and some spectators became passengers. They had to stand and were provided with a handle made from orange plastic. In this configuration they watched the movie, which alternated sequences of travelling the underground (which accelerated, growing noisier and more hectic) with the presentation of stills at a calm and slow pace. The interaction design students have also explored different ways of gaining embodied experience of digital media such as perceiving a situation of use differently by changing light conditions, mimicking use in body pantomimes or interacting with installations with body movements.

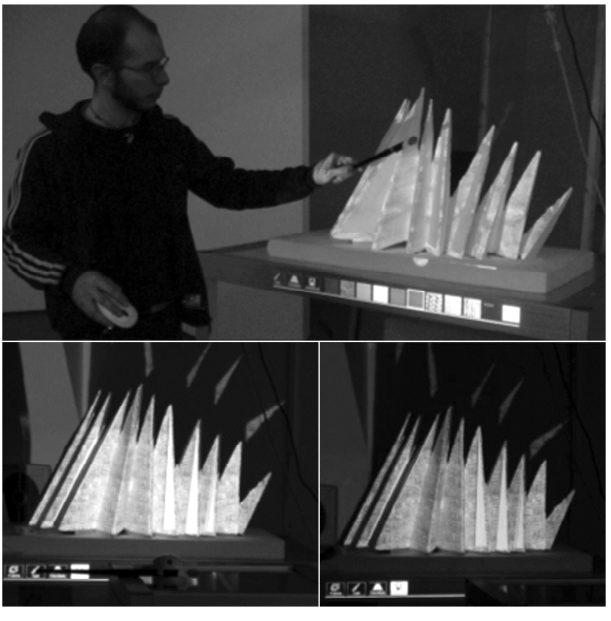

Fig. 2. With the *Texture Painter* design students are able to “paint” various computer generated visual overlays as textures on physical 3D models in real time. Using a brush, which is tracked, this application allows “painting” on objects such as models or parts of the physical space, applying textures, images or video, scaling and rotating them

The “bath room” scenario is another example of how students built a stage for enacting around a paper mock-up of their design of a fire alarm system with capabilities for user to user communication. They had played around with different scenarios trying to stretch their notion of the interplay between everyday settings and the artefact. Using very strong and sterile light coming from behind provoked a discussion on what really was important for the interactional setting. In back projections the interior of a bath-room was displayed. Moving the situation of use from the living-room to the bath-room made the students rethink their notion of what made us comfortable in a situation of communication.

Yet another example is how interaction design students performed an exercise in filming different situations of work or use of technology. Coming back to the studio

they played their films in large projections as a backdrop for their enactment. They were supposed to learn the body movements in the film so that they could imitate the situation without talking or commenting to each other. By doing so they experienced just how long time it takes to perform a certain activity, for example how much you actually have time to think while filling the gas into the tank. It is also possible to conceive of how body movements can affect the placing of interface components in a specific setting.

The performative elements of an installation are valuable as they are complementary to working with more abstract mental models of representation. One example is how interaction design students approached the design of an interactive installation at the Central Station in Malmö. Shifting between 3D drawings, sketches and embodied enactment, they gradually narrowed down their concept. Actually starting out from experimenting with different zones of light and ambient sound sources they made a 3D model of a tent. The tent recorded the surrounding environment with a web camera and sound recorder. Inside the tent the user could manipulate sound and vision by computer generated filtering, thus creating a personalized experience of a space. The students" way of working commenced with performing with the body and then got into sketching. Very often traditional working mode is the opposite, starting out with for example sketching.

In the *Interactive stage* (Figure 3) architecture and technologies can be easily configured for experimenting with immersiveness and scale and for using the performative elements of space. Immersiveness can be obtained with simple means, using several projectors and projection screens, "projecting everywhere". Students may use the space for enacting a design concept in performed scenarios, relating to it with the strong presence of the body. 1:1 scale projections of models and other objects may help them to discover new features of a material or a site, experience how a model or texture looks when it is blown up.

As part of an exercise with the aim to create an architectural view of objects, one of the first semester students had chosen a saw for cutting wood. He produced a series of sketches and drawings, took pictures of the saw in movement, build different models, and finally, explored his notion of architectural space in the *Interactive stage*.

The arrangement of projections screens helped the student to have all the different design representations – projections of the hand drawings, of the photographs of the model and the shadows it creates, the model itself - simultaneously present in the space. On a wall he had fixed a series of diagrams, photographs and sketches that explained steps of his investigation. In this installation the student moved beyond the 1:1 scale of a staged performance. Enlarging a small detail, such as the dents of a saw, or scaling a large building down to the size of a person and projecting them in spaces that are "inhabitable".

A physical model that the student had created out of the movement of the saw was placed on the *Mixed objects table* (Figure 4). The student used the *Texture painter* on his model. "Painting" the physical model became a performance and part of the design process; its informality and the imperfections of the product opened a space for associations and spontaneous changes. For the final part of his performance the student configured several sets of three pictures, using three projectors in the *Interactive stage*. Each picture set was assigned to a barcode and could be re-played on the three screens by simply reading the specific barcodes. The pictures enlarged details of models playing

Fig. 3. *The Interactive Stage* combines elements of a theatrical space with technological augmentations that are used to input, manipulate and output design representations, media, and events in the learning environment. The participant in the learning space is thus made a bodily part of the design representation. In practice, the architecture students mainly used the interactive stage for presentations, while the interaction design students used the space to enact use scenarios, engage in design improvisations

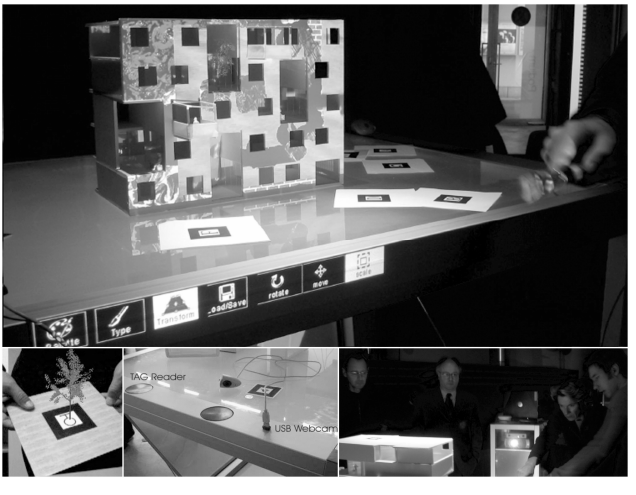

Fig. 4. *The Mixed Objects Table* is an artefact that allows students to combine real objects such as architectural models with virtual parts. It consists of a table top formed as a back projection screen. There are outlets for USB-Cameras, RFID-Tag readers and barcode readers integrated into the table frame. With a video camera and special markers virtual 3D objects can be added to the physical model on the table

with scale and immersiveness. Sets of pictures were used to show the relationships between models. A particular set was created out of close-up photo of the physical models and image processing (mirroring, stretching etc.). The three pictures where artfully montaged with the three projectors to create the perception of a space. Finally, while in staged performances the represented places may be imaginary and physical location and features of a site secondary, in everyday use it may be important to convey and re-produce specific qualities or features of a site. Students recreated spatial features of remote physical locations.

2.3 Configuring

For architects configurability is connected to the properties of a space. *Flexibility* connotes the possibility of relatively simple changes to a design so as to adapt it to different or shifting social uses (e.g. moveable walls). *Variability* means that a designed space or artefact, without elaborate transformations, can accommodate a variety of functions. Configuring and re-configuring, although with much more mundane means, is also part of students' practice. Students voice a strong need to adapt their workspace so that they can exhibit, perform, engage in group work or work alone, build models, have a nap, make coffee, interact with material and odd objects, etc.

At the beginning of a project the architecture students set up their workspaces. As the project progresses, they become dense with design material which is exhibited on

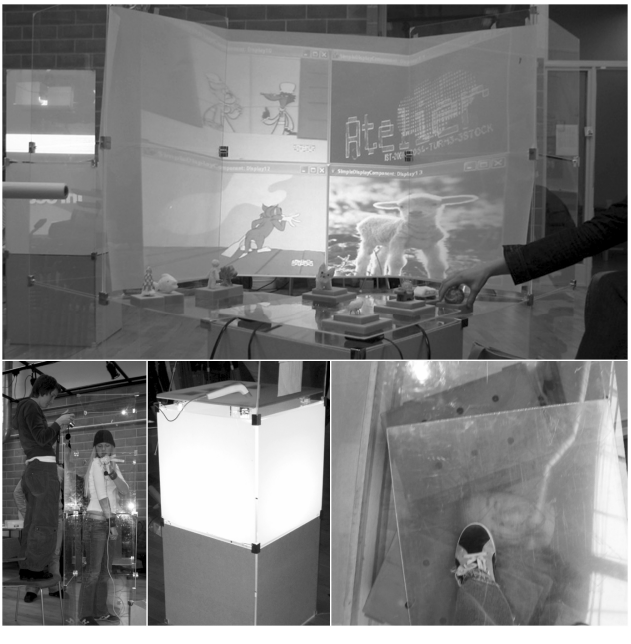

Fig. 5. The concept of the *Physical Building Blocks* was developed as architectural components meeting the need for "Getting out of the box" as well as on the basis of observations about how design students often work, experiment and prototype their ideas and concepts in a variety of places

the surrounding walls and on parts of the desk space. Sketches, plans, model, a panorama print of a site and the computer are all assembled in one desk space. In Malmö it was experienced that a theatre grid fastened to the ceiling in the studio provided a powerful possibility to re-configure the studio as to fit the activities. On the other hand it is a fixed installation that can only be used in the studio. In the workshop we started to explore how the project's technology could be used in assemblies configured by the students themselves. We wanted the students to be able to work in different places outside of the studio such as in the café area of the school or even on places outside the school. This required us to provide some physical building blocks apart from the technological components. The Plexiglas discs (48x48 cm) together with a set of different ready-made joints turned out to be a flexible system for building modules that were associated in different shapes. They have been used for building shelves storing project material, as containers for the technology concealing computers and cables or as mere components for building installations. The interaction design students have used *Atelier* technology in combination with the *Physical Building Blocks* (Figure 5) to mock up situations of use for ubiquitous computing, just like for example *Macromedia Director* has been used for prototyping screen based interfaces.

Fig. 6. *The Tangible Archive* is a "physical database" containing different design artefacts, tagged to carry links to digital media. It is a place for physical exploration and knowledge sharing within an environment of project-based work and learning. The main interaction point is the Organizing Zone. Technically the Organizing Zone is connected to the hypermedia database, a projector, loudspeakers and a printer. It also has a barcode reader and two RFID tag readers. It offers possibilities to view and simply manipulate entered media as well as to create a personal collection of digital media and real things

The *Tangible Archive* is an example of a configurable platform-furniture utilizing the physical building blocks. The furniture can be used as a surface for doing work (with work zones being reserved for particular activities), as shelves for storing materials, or for projections. The interaction design students worked with the *Tangible archive* in a two-week design workshop. During the workshop they worked in groups to explore what we called semi-public places (a public library, a public park and a public square) and they were asked to design an interactive installation that conveyed what they found to be interesting qualities of the places they had studied. They made video, audio and still image recordings of the places they visited and they collected physical

items from the area. After an introduction to the *Tangible archive* they build a first version of the archive for the collected material.

The students used the archive frame to set the scene for exploration of their material. The group working with a public park made a table-like archive where collected digital material were connected to tagged leaves gathered in a heap in the middle of the table. Images and videos could be displayed on a sphere mounted above the heap and people where supposed to sit on the floor in a circle around the heap. The group working with the public square created a closed cinema-like space where one could experience the emptiness of the square on an October morning. The group working with the library built a counter-like structure using barcodes and barcode readers in ways similar to the way library staff register books. The barcodes are easy to recognize, but the RFID tags that can be either embedded inside the objects or easily concealed don't signal that they carry links to digital media. The students explored how dedicated zones for interaction could be designed in a way that indicated what could be done and what should be avoided. Those concepts were later refined in other demonstrators. The architecture students used barcode technology for configuring their workspace. They had printed out thumbnails of images and the associated barcodes and they were provided with "system barcodes" for configuring input and output devices – the various projectors/displays on the one hand the *Texture painter* on the other hand – and for saving particular configurations. These print-outs were easy to understand and to handle and the paper format allowed annotations of various kinds.

2.4 Creative Density – Multiple Travels

Inspiration has to do with particular qualities of objects, people, ambience, a place. It always emerges within a context. Objects or a place, for example, are not inspirational as such but may be so in connection with a project, idea, particular task. Fieldwork observations showed a variety of ways to support these inspirational moments. One is connected to what we call "creative density"; the possibility to engage in an immersive mass of material – design representations in different media, inspirational objects, etc. - supports intensity in design situations. "Creative density" offers the chance to encounter surprising or interesting combinations of objects. It also supports "multiple traveling" – students' repeating their journey through design material again and again, with different layers and aspects coming to the surface. One example observed, in a project concerning studies and concept development for football stadiums, is how students after returning from a visit to several stadiums in London, Lille and Paris, spread out the pictures they had taken on the table, arranging and rearranging them. While looking through the material, together and with by-passers, they started remembering, evoking encounters, telling each other stories. One of the students took a picture of the arrangement, thereby freezing the moment.

Another way to re-experience a site intended for design, that has been used both by students and researchers in the project, is to use collected media in design games. A goal of the games is to set up imaginary situations that complement reflective understanding of practice. The goal is to investigate and negotiate images of what happened. It follows the structure of an ordinary card game, played for fun. The cards were augmented with RFID tags that maintained links to the videos and images. By placing the card on a tag reader the media were displayed in projections on a table (Johansson and Linde 2004).

A special version of the game used the *Tracking Game Table* (Figure 7). In the set up the tracking system used by the *Texture painter* was utilized for tracking the position of the displayed media. Projected from above, the media attached to the playing cards were displayed on a table. As the game continued and more cards were played, the amount of displayed media increased. Films or images were displayed in virtual frames that could be manipulated on the table by a specially designed wireless mouse with a reflector that communicated with the tracking system. This allowed for moving the "media frames" around the table, clustering related stories together and structuring the collection of material into different groups of meaning. By using the mouse, players could also scale the frames, thus focusing on different media by enlarging it or scaling it down. In this way the game continued by collaborative interaction with the images and videos until a set of design narratives had been constructed that the group found to be valid.

3 Performative Interaction, Mixed Objects and Configuring of Place

Experiences such as the ones that we described helped us develop a deeper understanding of what the interplay between architectural elements, artifacts, integrated digital technologies, and performing bodies adds to design work. We express this under-

Fig. 7. *The Tracking Game Table* is a set-up which uses a tracking system, allowing manipulation of virtual frames in which images and videos are displayed. A specially designed wireless mouse communicates with the tracking system by a reflector. The frames can be moved around, scaled to different sizes and videos can be started and paused. Playing cards augmented with RFID tags carry links to media files, and when a selected card is held above a tag reader, the media is displayed in a new frame

standing through a series of concepts: Embodiment and the performative elements of space, mixed objects, configuring and place making.

3.1 Embodiment and Performative Elements of Space

Paul Dourish has introduced the concept of embodied interaction (Dourish 2001). This stance is grounded in the phenomenological tradition, focusing on the phenomenon of *experience*, approaching phenomenon as they appear to the experiencer. Our everyday life-world, just as work practice, consists of concreteness, and calls for collecting the paradoxes and complexity of life worlds rather than unifying them in abstractions. While abstraction seems to be one of the foremost strengths of computation and digital media, it is evident that users are more than information processing systems. The relation between information and knowledge is one example of how meaning is not inherent in information, but rather made meaningful through direct participation in the world. An important facet of Dourish definition is how "embodied interaction is the creation, manipulation, and sharing of meaning through engaged interaction with artefacts" (Dourish 2001). A shift towards embodied interaction is motivated by the recognition that to accommodate a broader understanding of human potential requires moving computation "out of the box" and "into our environments". The notion of embodied interaction addresses how a situation must be considered as a whole. Meaning is created in use of shared objects and social interaction is related to how we engage in spaces and artefacts. In this interplay the body has a central role, in many ways the body can be seen as the medium for having a world. This is a perspective that differs from "disembodied" use of computers and interactive systems.

Our contribution to this line of research has been by investigating the notion of embodied interaction in a real setting. The specific contribution consists in revealing with the *Atelier* trials the *performative* character of interactions involving space, artifacts, digital media and multiple participants (Jacucci et al. 2005; Jacucci 2004). Therefore the use of the adjective *performative* resulted from articulating the concept of embodied interaction further, characterising how it features in a specific setting. This aspect of embodied interaction is gaining relevance in view of attempts of using tangible computing or mixed reality for art and entertainment (Benford et al. 2006; Hämäläinen et al. 2005) but can be relevant in work and educational settings as well (Bannon et al. 2005; Ciolfi and Bannon 2005). The term *performance* can be taken to address everyday life, and can interest a variety of situations beyond theatrical performances and rituals. It is relevant in this discussion as it stresses the event character of action and interaction, as it is about bringing something to completion that has an initiation and a consummation. It indicates an ephemeral and contingent process to particular socio-material-historical circumstances. Moreover performance points to expression and individuality as embedded in people's actions and movements, but also in space and artefacts. It may be considered in the creation of artefacts or architectures, especially in the ways these carry a performative potential that is unleashed through participant's interactions (cf. Acconci's Performative Architecture (Sobel et al. 2001)). *Performance* implies an act of expression directed to others and, dissimilarly to behaviour that is not performance, more efforts in terms of energy, skill and consciousness (thinking) of the acts. Performance proposes a simultaneousness of action and experience, of presence and representation; in Dewey's terms a structural

relationship between "doing and undergoing" (Dewey 1934). This in turn points to how expressions can contribute to perception and therefore to new insights, either in their act of creation for the "creator" or as embodied artefacts in their material and immaterial qualities for an "experiencer".

We found different kinds of performative interactions in the field trials:

Performative artefacts. Artefacts augmented with sensors and tags were "scripted", associating images and sounds to different interactions. The artefact in these cases does not unleash its communicative potential by just being observed and scrutinised, but a participant must interact with it activating the playing of digital media. Interactive technology exploited the articulation in material qualities, spatiality (touch sensors in a solid section that becomes an interactive skyline) and affordances (turning the pages of a diary) rendering them more expressive. Artefacts acquire meaning through material qualities, their spatiality, and the way participants interact with them. This is evidence of how physical interfaces, supported performative uses of artefacts, moving beyond the simple tagging or tracking of an artefact.

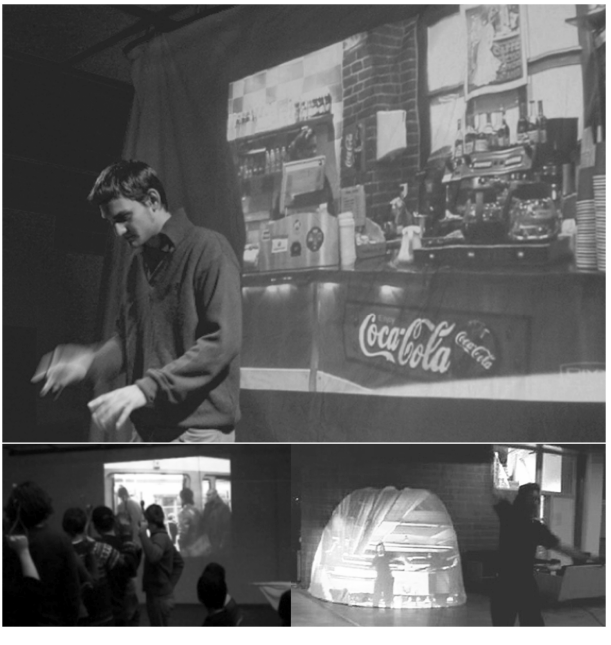

Fig. 8. Embodiment and performative elements of space – students mimicking a filmed work situation, re-enacting a joint field trip and experimenting with the body as interface to an installation

Staging Spatial Narratives. Performance stresses how meaning is embodied in the careful and expressive arranging of elements in the space. The students played with scale and immersiveness creating inhabitable spaces with multiple projections. In these cases the spatial configuration is not neutral but concurring to narrate the concept; it is a narrative use of the spatiality of projections. The bodily presence of spectators is carefully taken in considerations and in some cases spectators became par-

ticipants contributing to the representation (becoming the audience of a stadium or passenger in a train).

Staging and performing "mixed objects". "Performance", in this case, refers to how these configurations can be seen as staging and performing objects that are both digital and spatial. These exist for a limited time; they are ephemeral, although they can be saved and reloaded (to some extent). As performances, they are recorded with pictures or through videos or they have to be performed again. Their potential reaches beyond "mere embodiment". *Such "mixed objects"* provide the means for producing configurations that change spatiality, interactivity, and physical landscape in ways that help people experience, explore, present, and perform.

3.2 Mixed Objects

A rethinking of the borders between material and digital is needed. The paradox of *demassification* is an expression introduced by Brown and Duguid several years ago (Brown and Duguid 1994)**.** What they pointed at is how digital technology and new media introduces new material and social conditions for the design of artefacts. Demassification concerns the *physical* or material change - artefacts literary lose mass and can be distributed and accessed globally. Think of a digital book or a library. But there is also a *social* or contextual demassification. This concerns the possibility to customize and make individual copies of digital artefacts - a loss of mass in the meaning of a mass medium. Again think of a personalized version of the book or the digital library. Why is this a design problem? Is it not just great with totally mobile and individualized artefacts? As Brown and Duguid suggest with their paradox of demassification this is achieved at the prize of lost intertwined physical and social *experiences* of the artefacts. The physical demassification deprives the artefact of material "border resources" for shared interpretation. The cover of the book may not be decisive for the content, but its shape, texture, weight and not least "wear and tear" may still be an important aspect of its "bookness" and how we experience it as a book. These "border resources" are lost when every digital copy gets its own form, and hence a relatively established source for interpretation dissolves. Entangled with this, and adding to the problem of lost physical mass, is the social demassification. The individualized versions of a digital artefact, reaching only a few persons, underline the loss of shared "border resources" by jeopardizing a relatively stable contextual resources for shared interpretations within a community. It seems that a feasible design strategy must find ways to counter this loss of mass. This challenge is in line with the perspective of embodied interaction and the understanding that we today have to design digital technology for interaction that is both more tangible and more social.

Embodied interaction does rethink the borders of the digital artefact. Starting from the position that our interaction with artefacts, also digital artefacts, is experiential, we suggest accepting that there is no such thing as an entirely digital artefact. Instead the design materials for digital artefacts are both spatial and temporal. With digital technology we can build digital temporal structures and behaviour. However, to design these temporal structures into artefacts that we can experience and interact with almost any material can be of use in the spatial configuration. Hence, design of digital technologies deals with, what De Michelis (De Michelis 2004) calls a kind of *mixed objects*, including "border resources".

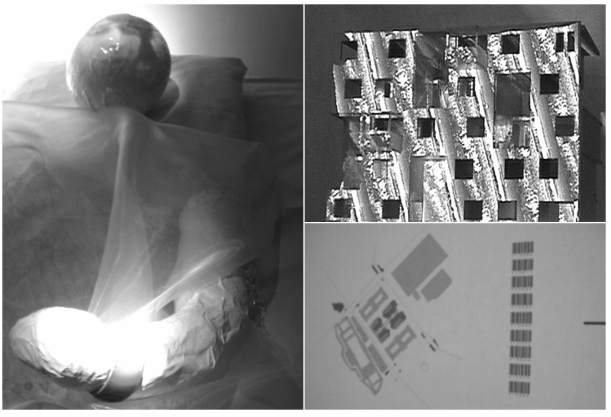

Fig. 9. Mixed Objects – Interactive projections on a physical model, architectural model overlayed with digital textures and CAD plan with barcodes

In preparing a project presentation one of the architectural students plotted out her CAD plans with barcodes on them. In one of her print-outs she had integrated the barcodes into a diagrammatic representation. She presented her work using multiple interactive artefacts that triggered the playing of sound and visual media on a projected screen. Barcodes were integrated into posters, which displayed plans and diagrams. A physical model of the section of the stadium was made interactive with touch sensors. The CAD drawing with barcodes was a first example within the project of *mixed objects*, where integration of the physical and the digital happens within one single object. This notion goes beyond simply enriching a physical artefact by linking it with content in different media. A characteristic of these animated or *mixed objects* is that you have to interact to experience them. By integrating barcodes into her CAD drawing, the student created a new way of engaging with the design artefact. The diagram does not speak for itself - you have to physically interact with it. In the case of the *Texture painter* with which students worked in the second round of field trials the link is such that the properties of the artefact itself can be changed, by applying colour, inserting movement and context, and varying its dimension in relation to other objects in the physical space.

These and the many other *mixed objects* the students created can be characterized by a set of qualities:

- *Openness* refers to how accessible and learnable an artefact is, and to its capability of being combined with other artefacts. Moreover, openness refers to the capability of an artefact (an affordance) to have different, potentially unlimited, ways of being used and perceived. Our experience of providing students with simple prototypes, helping to extend them and furnish them with more complex functionality is an example of openness to appropriation and use. Another crucial aspect of openness is the possibility for an artefact to be combined with other artefacts. Integrating barcodes, tags, and touch sensors in physical models and diagrams helped create interactive and in some cases innovative combinations of physical and digital objects, being perceived and used in many different ways. The *Texture painter* and optical markers, applied in combination with physical objects and projections, resulted in rather intriguing kinds of *mixed objects*.

- *Multiplicity* refers to the capability of a space or artefact of being made of different components having different qualities. Multiplicity can be seen in the combination of input (sensors, tag and barcode readers, scanners, etc.) and output (displays, printers, projectors, etc.) devices characterising the workspace of the students, and/or in the multiplicity of affordances offered by *mixed objects*.
- *Continuity* refers to the capability of moving from one affordance to another, from one representation to another, without changing artefact, without interruption in space and in time. It can be achieved by putting resources on the borders of objects, so that the borders act as both, separators and connectors.

In the design of *mixed objects*, where digital content is integrated in the physical object, there seems to be a vast array of possible levels of integration. While in some cases digital media are just "put on top" of a physical artefact, other examples are more profoundly integrated and digital and physical properties operates within one single object. The difference could be illustrated with the concepts of "collage" as opposed to "sampling". While the older montage form collage is juxtaposition by putting things next to each other, sampling works on a more genetical level and constructs genuine hybrid forms.

An important design strategy for construction of *mixed objects* is to mobilize a great quantity of materials in order to maintain the border resources. Basically any material could be used and different qualities can be supported with different combinations. One example is observed by Redström (Redström 2001) in how LCD displays seems to dominate the overall expression more directly, as opposed to projecting on fabrics. During periods in the project we have pushed this notion one step further, trying not to use any generic displays at all. Integrating space can also be to use whatever surfaces that are available, for projecting upon them, accepting constraints in resolution and light conditions. Freedom in combination of materials will also affect the modalities that will be addressed in perception.

Design objects are also mixed in a social dimension in the sense that they are being shared and the notion of *boundary objects* (Star 1989) is relative to the paradox of demassification. Design artefacts from the Atelier project such as the *Interactive Stage*, the *Tangible archive*, the *Mixed object table*, the *Texture painter* as well as the physical models and project plans enriched with barcodes, or touch sensors, are all examples of boundary objects, or allow the creation of boundary objects. The concept of boundary object can be extended to anything that can help people from different communities to build a shared understanding. Boundary objects will be interpreted differently by the different communities, and it is an acknowledgement and discussion of these differences that enables a shared understanding to be formed. It should be clear why a physical model or a sketch may serve as boundary objects, helping visitors to understand what students do in their projects; whereas the more technical and detailed representations, such as a CAD plan, are only boundary objects for the more specialized professional communities of architects and building specialists (Schmidt and Wagner 2003).

We consider the artefacts we have created to support multimedia representations as boundary objects. They are potential boundary objects, since they allow visitors to share with the students the knowledge about their design space (and the constraints

and the opportunities it offers), as well as bring different perspectives onto an object to the forth. Our artefacts support this mixture of commonality and diversity, offering the possibility to move from one representation to another, either changing level of abstraction, or changing supporting medium or, finally, changing viewpoint. Users can access several different representations making reference to one unique thing (the designed building and/or device, the planned territory and/or space, etc.).

In our approach, boundary objects are intrinsically multi-affordance objects, where commonality is supported by the emergence of one unique object, and diversity by the multiplicity of affordance through which users can access and manipulate it. Considering the experiments we have done, some of them deeply adhere to this concept (e.g. the *Texture painter*) while others have not yet fully developed it (in some cases any representation seems to have its own life and its links with other representations of the same object are not highlighted). Our boundary objects, therefore, are often and should always be *mixed objects*, i.e. objects coupling physical and digital qualities. Even the concept of boundary becomes broader than in its original definition by Star, it refers to the contact line not only between different communities, but also between the physical and the digital, and, as a consequence, between the different (spatio-temporal) situations of any user.

3.3 Configuring and Place Making

With the perspective of embodied interaction both the social dimension and our bodily experiences come into focus. As Dourish has argued in his call for embodied interaction *place* reflects the emergence of practice as shared experience of people in space and over time (Dourish 2001)**.** When people share an enriched portion of space and a language to talk about their experience, they transform space into a place. The design challenge is not to design space, but to design for *appropriation* of space according to the activities that take place among a particular set of people inhabiting that place.

Architectural space is not static, it constantly changes with people's activities. The notion of "use-as event" (Lainer and Wagner 1998) emphasizes the changing, evolving, temporary and sometimes performance-like character of activities in space. It is resonant with Tschumi's idea of "architecture not as an object (or work, in structuralist terms), but as an "interaction of space and events". His ideas revolve around choreographed, "cinematic" movement (in time, through space), and through this he arrives at an alternative way of looking at the materiality of architecture as "in its solids and voids, its spatial sequences, its articulations, its collisions" (Tschumi 1981, in Nesbitt 1996). At the same time, a space is not neutral, it is a space for something, being furnished with specific practices, artefacts, symbols, knowledges, and ideologies. It provides actors with a "view from somewhere" (Haraway 1991), a special vision. Smith (Smith 1990) emphasises the possibility to locate and identify positionings as a precondition of knowing. A particular script, she argues, can only be produced at a particular place. This notion of space as shaping social practices on the one hand, being constantly changed by the people who inhabit and use it –"use as event" – on the other hand, needs to be kept in mind when thinking about how to implement particular qualities in the spatial design.

Fig. 10. Configuring and place making – the students appropriating the design studio to different uses

Configuring as a practice is intricately linked to the fact that in evolving environments, such as the architecture class or the interaction design studios, the boundaries of activities are continually moving**.** Our observations helped identify two meanings of configurability:

- Adapting a space to a diversity of uses and identities – which is achieved through e.g., appropriating a space, personalizing it and configuring it in support of diverse arrangements, such as solitary work, group discussions, performing and presenting, building models.
- Configurations of artefacts within the physical space – with artefacts changing the position in relation to others, and different configurations expressing the conceptual, chronological or narrative links between them.

As to the configurability of a space, we could learn from good architectural design that often plays with an ambiguity in the relationship between spatial configuration and functional program, where

> *"The allocation of functions or uses is malleable, they are fitted into the spatial configuration. While some of them find ample space, others might have to be squeezed in, overlap, extend into neighbouring spaces, thereby creating 'natural' connections or meeting 'fixed' boundaries. This not only allows to suspend or transgress the usual hierarchy of functions and rooms. Also, the boundaries between interior and exterior space are designed as permeable and fluent" (Lainer and Wagner 1998).*

One conclusion to be drawn from this is that a learning space needs not to be perfectly equipped and designed. On the contrary, a certain lack of perfection, the presence of spatial constraints may be important, since they stimulate activities, the creative appropriation of the space, its re-programming for changing events and

needs. Hence our approach of designing architectural components that can be assembled and configured for specific purposes on the one hand, our notion of an architecture as augmenting existing spaces on the other hand. Embedding digital media in physical environments cannot be simply understood as an extension of practices we observed in the physical world. Things need to be designed so as to support "the ability to improvisationally combine computational resources and devices in serendipitous ways" (Weiser 1993). Hence our strategy not to create new and dedicated artefacts but to encourage students to embed digital media in the diverse design representations they customarily produce.

At the beginning of our field trials with the students the space was unformed and had to be appropriated. Our pedagogical assumption is that a perfectly furnished space is often not the best solution for creative work. Students need to appropriate the space, struggle with its constraints, and find their own interpretation and set-up. This is why they found the space almost completely empty, apart from an infrastructure of networks, furniture, grids for projections, tag/barcode readers, computers, and other electronic equipment. They were asked to bring their own stuff – pictures, video material, scale models, diagrams, and collages. With these resources at hand, students configured and re-configured space and artefacts to accommodate diverse activities – from browsing through pictures, to discussing a design concept or performing a scenario of use. We can understand these configurations as forming an evolving set of temporary, and, in some ways ephemeral layers onto this neutral, almost empty environment.

We could discern several overlapping strategies in how the students appropriated and configured space, such as: personalizing (equipping it with things that reflect their personal identity and preferences); configuring furniture and technical equipment for a particular task; configuring the space to accommodate visitors, a large number of people, eventually observing a particular ritual of stage/spectators or seating habits; configuring a space for cooperative work, etc. The associated movements of equipment and people reflect the notion of "use as event" and the performative/choreographic elements in how space is integrated into different activities.

As suggested by Dourish in outlining embodied interaction, the philosophy of language-games, as developed by Wittgenstein, is an interesting approach for understanding social and tangible practice (Dourish 2001). This is in line with a position to design as intertwined with *language-games* (or overlapping communities of practice) that has been the basis for much of the research in participatory design during the last twenty years (Ehn 1998). The idea of language-games entails and emphasizes how we discover and construct our world. However, language is understood as our use of it. As we see it, this is not in opposition to how we also come to understand the world by use of physical artefacts. Objects also play a fundamental role in a given language-game. In this view language-games are performed as practice with "embodied" meaning within societal and cultural institutional frameworks. To possess the competence required to participate in a language-game requires a lot of learning within that practice. But in the beginning, all you can understand is what you have already understood in another language-game. You understand because of the *family resemblance* between the language-games. This seems to make us prisoners of language and tradition, which is not really the case. Amongst others, Habermas (Habermas 1968) pointed to the flexibility and reflexivity that is built into our everyday language, as al-

lowing us to learn, to modify, extend and subvert meanings. Being socially created, the rules of language-games, as those of other games, can also be altered.

In participatory design users and designers are fundamentally seen as related via shared experiences in a common design language-game, where the design artefacts like mock-ups, prototypes, scenarios can be seen as boundary objects. This language-game has a family resemblance with the ordinary language-games of both users and designers. A fundamental competence of the designer is the ability to set the stage and make props for this shared design language-game that makes sense to all participants, making the interaction and mediation between different language-games possible.

In a critique of the dualism of virtual reality Hedman comes up with an interesting suggestion along these lines: What if we think of the activities going on in a place as a kind of language-games. He calls them *place making games* and suggests that places allow for multiple place games (Hedman 2003)**.** In studying an exhibition with *mixed objects* in a museum environment within the SHAPE project, exploring an environment with strong similarities to the *Atelier* tangible archive, he observes that visitors may shift between different games during a single visit. Moreover, the kind of place games that can occur constitutes an open ended set of activities where digital elements are joined into an, as he calls it, "esemplastic unity" through the place making games that are played. This concept for moulding diverse ideas or things into unity, borrowed from Coleridge, suggests design for place making uniting corporal and incorporeal spaces rather than adding a virtual reality to the one physical already existing.

The concept of incorporeal places is by no means limited to digital technology and virtual reality. As Hedman writes:

"… humans have always been actively engaged in incorporeal places, whether in art, sleep, through recollection, imagination or fiction. Incorporeal places have always been part of everyday life. Certain disciplines and traditions have put special emphasis on incorporeal places: in religion-heaven and hell, in architecture-the planned building, in art of memory-the information place, in fiction-the place of action and drama" (Hedman 2003)**.** The art of memory, e.g., as practiced by Cicero, rests on the capacity for places to be associated with things to remember. An example of a such public and tangible place was the memory theatre as described in the sixteenth century by Giulio Camillo. This esemplastic place allowed users to enter a cylindrical room where the walls were covered with systematically marked and located little boxes and carvings. From a stage the user was overlooking the totality of human knowledge and it was said that anyone entering the room instantly would be as conversant as Cicero on any scholarly subject. Be that as it may, memory theatre and the art of memory also open up a perspective of story telling and associations relevant to the design for contemporary esemplastic places. We are here reminded about the observation by Ricoeur about narrative time and how the story told not only gives an historical account, but actually also takes place here and now organizing the current activities (Ricoeur 1984)**.**

A good example from the Atelier project of a design for esemplastic unity of place is the tangible archive. The use is informal like in a "Wunderkammer", and it is more associative than in a systematically organized traditional archive. Maybe not an environment that makes the users as conversant as Cicero, but an open environment for appropriation of space in the activities that take place among several people being bodily present, when acting with mixed objects as they make sense to the place. An-

other example are the semi-immersive spaces created by multiple projections. They allow to mesh times and spaces, presence and distance.

The examples we have provided explore different aspects of configurability of mixed environments: associations of inputs, media, and outputs; spatiality and integration with artefacts; configuring furniture and work zones (Tangible Archive); real time configuration of mixed objects (Mixed objects Table). In all examples configurability and place making includes interventions in the physical landscape of space and artefacts. The complex activity of configuring unfolds, and therefore has to be supported, on different levels and across different aspects of the environment: spatial arrangement (e.g. grid for fixing projection surfaces), furniture (the Tangible Archive with its modules, the table), the landscape of artefacts which can be tagged, furnished with sensors or barcodes, electronic components and devices (scanners, readers, connecting and plugging input and output devices), digital components and their interactions (digital infrastructure, associations of inputs, outputs and media content in the database) (Binder et al. 2005; Ehn and Linde 2004).

This large variety of means can provoke confusion among both users and designers. Users are unable to find a rationale to deal with the new qualities of the space where they act and designers miss the compositional grammar for creating their devices and arrangements. Even the weaknesses of the space offered to users can be attributed to the lack of a conceptualisation shaping the design of tangible computing environments. We were, therefore, somehow forced to enter into a discussion of the qualities the artefacts we were designing had and/or should have. This discussion, on the one hand, has created a deeper understanding of what we were doing in Atelier, on the other, indicates new possibilities for the design for configurability that we have not yet pursued in our research.

4 Out of the Box

We started the *Atelier* project with the ambition to create inspirational learning environments in the spirit of Weiser's vision of taking the computer "out of the box" and making computational resources augment the design studio environment ubiquitously. This led us into design of architecture and technology in support of design qualities in action such as design work as transforming representations, performative interaction, configuring, creative density and multiple travels, and conceptual work in direction of embodiment and the performative elements of space, mixed objects, and configuring as place making.

As a final reflection we could say that in a way this attempt turned out to be too successful. To our surprise we had helped augment the studio environments so well that the students voluntarily got stuck in there, rather than going out exploring practice in the world. We had re-created the computer in a box, only now on the size of a studio. Hence, in rethinking the design studio as a creative environment, portability and flexibility of technology for configuring and making place became central. This required a change of perspective towards regarding whatever space there is available as a potential inspirational learning environment, and *Atelier* technology as a way to configure that space, herby potentially shaping *mixed objects* and esemplastic spaces for meaningful interactions and place making games of design and learning.

Fig. 11. Out of the box…

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