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Exploring relationships between learning, artifacts, physical space, and computing

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Abstract

Despite the interest in physical interfaces, field studies directly informing development and field trials of prototypes are rare. Particularly rare are design projects that integrate the space and existing artifacts as a resource. We report on the development of an interactive learning environment in support of students of architecture and interaction design. Based on ethnographic fieldwork we specified a set of qualities of the learning environment, which guided the development of physical interfaces (using tags, sensors, video tracking, physical and digital infrastructures). To investigate how students would integrate technologies in their work settings we have organized field trials with open prototypes. These showed the value and some means of mixing evolving artifacts with digital media. In interactive installations students used the space as a stage to experience and explore aspects of places and situations.

Keywords: participatory design, physical interfaces, ubiquitous computing, prototyping

1 Introduction

The topic of this paper is the design of an interactive, tangible learning environment in support of students of architecture and interaction design. There is a growing corpus of literature on physical interfaces, ranging from working with tangibles and wearables to augmented and virtual reality environments. Much work has been done on stand-alone interaction devices, on augmenting existing objects such as books and workspaces (e.g. Want and Fishkin 1999), as well as on more elaborate designs in support of activities such as story-telling (Stanton, Bayon, et al. 2001) or game playing. Much less attention has been given to the physical environment, the combination of space and artifacts, and to how these shape action. Within IST project Atelier we: 1) explored approaches to mixing physical and digital artifacts, 2) experimented with ways of integrating the physical space into the students' learning activities, and 3) investigated the possibilities of configuring the environment.

Our study operates with the notion of key qualities of a learning environment to be maintained and supported. These key qualities were identified through fieldwork at the Master Class of Architecture, Academy of Fine Arts in Vienna, and the Interaction Design Studio, Malmö School of Art and Communication. At both sites learning does not take place in traditional classroom settings. It is project-based, helping students become part of a profession through the improvisational development of new practice in a diversity of role configurations (Lave

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and Wenger 1991). We developed a set of technological and architectural interventions in support of these qualities and carried out field trials with the objective to evaluate and further develop these interventions.

1.1 Computing, space and artifacts

The challenge of tangible or ubiquitous computing is to integrate with the physical environment of artifacts and spaces (cfr. Ishii and Ullmer 1997, Mackay 1998, Weiser, Gold and Brown 1999). Dourish addresses this concern with the physical environment, introducing the notion of embodied interaction. People's bodily interactions within physical space "offer opportunities for a much more direct apprehension of the modulating, mediating effect that computation plays in interaction", with the active nature of computers being important not as independent agents but "as augmentations and amplifications of our own activities."(Dourish 2001 166). One of the few empirical studies of embodied interaction was carried out by Heath et al. in a museum setting. They use the term 'active spectator', pointing to the "relevance of the ecology or setting in which a painting or sculpture is positioned, and to the ways in which the spectator actively 'connects' features of the object to action within the local milieu" (Heath and Luff 2002 11).

In a recent contribution on future ubiquitous domestic environments Rodden and Benford (2003) look into work about how buildings change as a source of inspiration for defining research agenda for designing technologies. One of their arguments is that technology designers predominantly concentrate on the interior of stuff, space plan and services, while neglecting the exterior of site, structure and skin. Among the few design approaches that explicitly include the physical environment is 'Roomware' (Streitz et al. 2001). They use the notion of 'cooperative buildings', thereby emphasizing that the starting point of their design is the real, architectural environment. Buildings not only support cooperation and communication. They can be made responsive to their users' needs "by employing active, attentive, and adaptive components." However 'Roomware' are pre-designed tangible computing products for general meeting purposes. Research on developing augmented environments is rarely based on field trials in naturalistic setting (cfr. Abowd and Mynatt 2000). Equally unexplored is the issue of how computing can be integrated with artifacts that evolve in the process of work and how it can be used for reconfigurating the physical environment in support of different activities.

1.2 Field study and development method

Although our research activities are held together organically by participatory design principles, they followed no strict methodology, and we made opportunistic use of a wide range of resources and techniques. Extensive fieldwork was carried out at both sites over the course of several months, based on video-supported participant observation of design practice and on interviews with students and professional designers. In this fieldwork we took a view on the environment as a whole, with a focus on the materials and artifacts through which an architectural or interaction design evolves and on the use of the built architecture as a resource for learning. The fieldwork material helped understand design practice and identify key qualities of the two learning environments. Based on this material we looked for opportunities for technology-support, developing a set of prototypes and scenarios of use, and designed field trials at both sites. Our strategy for these field trials was not to create new and dedicated artifacts and spaces but to motivate students to integrate the prototypes into ongoing project work. This was enabled by what we see as the 'open-ended' nature of the prototypes. There is an increasing interest in enriching design practice by using

tools and concepts that help raise topics and ask questions. For example, Gaver et al (2003) work with the concept of ambiguity as a resource for design as it "provides a frame of reference that allows the use of inaccurate sensors, inexact mappings, and low-resolution displays because it encourages users to supplement them with their own interpretations and beliefs." Hutchinson et al. (2003) propose technology probes as a co-design method, where simple and flexible technology is installed and observed in a real setting. While technology probes are not changed during the use period, the prototypes we provided are open to reinterpretation by participants and can be tailored by them. We facilitated this process of active appropriation by making extensions to the prototypes whilst students were experimenting with them. Developing for and experimenting in such natural settings is a task that is very different from evaluating tangible computing systems in laboratory tests (e.g. informal evaluation as in Everitt et al. 2003).

In Vienna the prototypes were made available from November 2002 to January 2003 to the architectural master class, which had The Stadium as City as its topic. We also followed the work of three students on their individual stadium projects. During the summer semester we were able to observe students' work on a large 'operational model' of a site for a stadium. During the same period the students in Malmö worked on a design project named Augmenting places for collaboration. Prototypes of the technology were available along with a staff of researchers, teachers and programmers acting as tutors but also making adjustment to the technologies in accordance to students' wishes. After examinations the concepts were exhibited as interactive artifacts and the students were invited to participate in the analysis of the field trials. This was set up using the RFID components for creating game-like sessions where episodes from their design work were negotiated.

2 Stories of design and use

Based on the analysis of the observations of student work and on interviews with a small number of practicing architects we specified a set of qualities of a learning environment (see Iacucci and Wagner 2003, where the qualities are introduced using observational data from only one site). These qualities are interrelated and there are many ways of interpreting and supporting them. In this paper we in particular refer to the following qualities:

- Materiality and the diversity of materials and representations – design work proceeds through developing a large number of design representations, with materials playing a crucial role in envisioning particular aspects of a design
- Re-programming and the 'different view'– the design process requires to continuously transform and 're-program' familiar settings
- Forging connections/multiple travels - a crucial aspect of the design process is to maintain evidence of all the material that has been produced, to forge connections, and to create and explore different perspectives
- Configuring - the adaptability of a space to a diversity of uses and identities

The 'qualities' have proven to be very effective, in guiding technology development and in interpreting the field trials. In the following we present selected episodes from our fieldwork and trials on two different design themes: physical artifacts and digital media, and connecting, configuring, and integrating the physical space. Within each theme we 1) portray the qualities of the environment we intended to support, giving some examples from our field work observations; and 2) describe our technological interventions and how these merged with the existing design practices and changed them.

2.1 Physical Artifacts And Digital Media

Materiality, the diversity of materials and representations Both, the interaction design and the architecture students, work with representations in different media. The materiality of some of these representations plays a crucial role in envisioning particular aspects of a design.

For example, architects work with a great diversity of models of different degrees of abstractness. The physical features of the material often carry meaning. Figure 1 shows two of several models students built of a mountain resort. While the plastic implant in the model of a building on the left visualizes "something that flows out of a crack in the mountain", the half-relief on the right of the section of the same building highlights particular details of the spatial design. ¨

Examples such as these 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 (see Want and Fishkin 2001, for a comparison of tag types). They used these technologies mainly for animating design artifacts through connecting them with multi-media files. The interactive installation in Figure 2 shows a dummy representing a patient in a hospital. By pushing the button on a bracelet the visitor changed the projected facial expression from pain to relief. One of the projects we observed was about making visual and material studies starting from a working tool (e.g. saw). The architecture students first made studies of a tool by analyzing its form. They would then have to create three-dimensional models from the movement of the tool in use. These studies produced a series of visual and material explorations on drawings and several models for each tool.

These were presented interpreting the created forms. Each student placed several models on a table, the sketches and drawing on a board, and showed sets of three pictures of the models on three large projections screen. The immersive three picture presentations, showed studies created through photographing the model in a variety of conditions, exploring the materiality of models (Figure 3). The

Figure 1. The diversity of representations

Figure 2. 'Dummy patient'

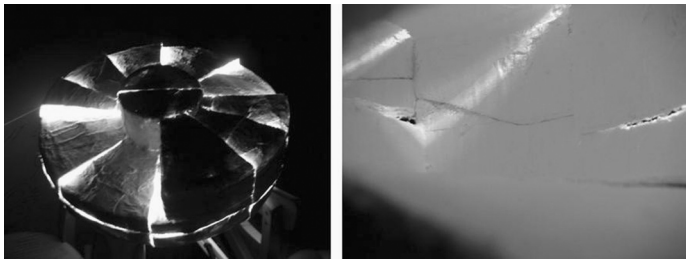

Figure 3: Photographing models with under conditions.

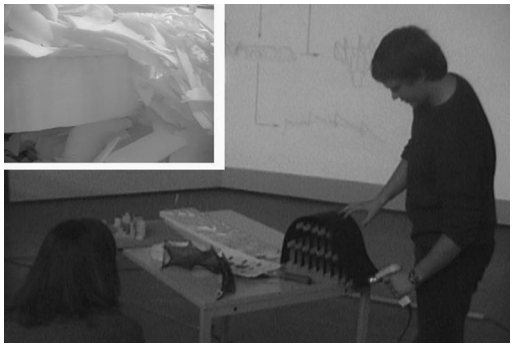

Figure 4. Barcodes on models are associated to three pictures on large screens

presentations were guided using barcodes on models and diagrams (Figure 4).

By scaling details of close-ups to large projection screens, they played with scale and immersiveness (Figure 5). These activities also point to the following theme of reprogramming.

Re-programming and the 'different view'. Creative work requires to transform and re-program - to explore solutions and contexts, to shift perspectives, to carry out experiments, to present and perform, to have time and space for free play and day-dreaming, and to generate a 'different view'. Interaction designers re-program by blending the perspectives of different actors or by disrupting social conventions of interacting.

Figure 6 shows two examples of re-programming activities that occurred in the interaction design studio. On the left a scenario was changed by use of light, moving the "warm and cosy living room into the cold sterile setting of the bath room", and perceiving use quite differently. On the right a "body mimicking" exercise is illustrated. By recording a situation of use and acting with the video as backdrop, you could for example experience just how much time for thinking you have while filling up the gas tank of a car. An example of re-programming from the architecture class is a feedback session with a student who proposed an underground parking space in her project of re-vitalizing an area with immigrant workers.

Her teachers challenged her approach, asking her to transcend the traditional categories by trying to combine them in new ways. To, for example, work with contradictions – "the mosque, outside lively, inside an oasis of tranquillity"; to let market and street reach into the park; to use empty shops for parking; to connect living with the car, its sound machine being used in the living space. Another example can be seen in Figure 7 where students used photomontage for turning a table in a deserted courtyard into an elegant dinner arrangement and for transforming an ugly industrial skyline into a ship. One of the tools we designed in support of re-programming activities such as these is the Texture Brush: using a brush which is tracked with a video camera, this is a tool for 'painting' objects such as models or parts of the physical space, applying textures, images or video, scaling and rotating them. Students started animating their models with

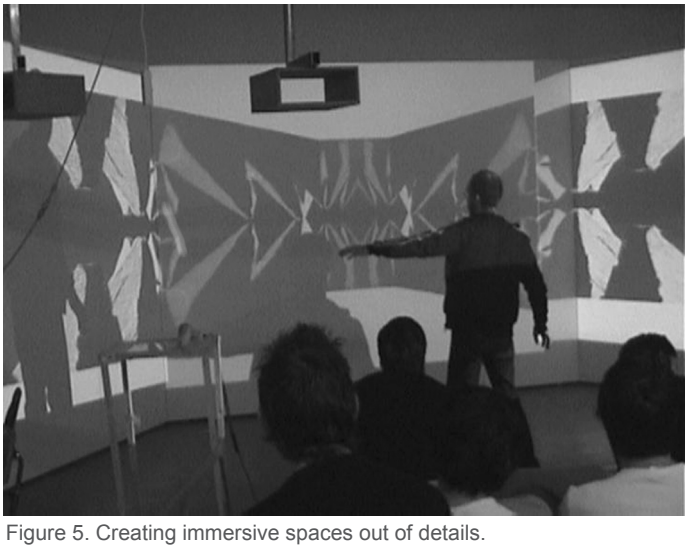

Figure 5. Creating immersive spaces out of details.

Figure 6. Using light for transforming the atmosphere

Figure 7. Seeing a derelict area differently

the help of the texture painter. As part of the project mentioned above (Figures 3,4, and 5) in exploring form and material starting from a working tool, one student chose a saw for cutting wood. He produced a series of sketches and drawings, took pictures of the saw in movement, built different models. A physical model that the student had created out of the movement of the saw was placed on the 3D Table. This is a movable piece of furniture with an integrated mirror and a semi transparent table-top, which can be used as a surface for placing objects and a display component. The student used the Texture Brush on his model (Figure 8). The Texture Brush provided a fast interactive way of experimenting with scale, colour, and background. '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.

2.2 Connecting, configuring, and integrating the physical space

Multiple travels. Students go back and forth between media and design representations as well as between the studio and places in the outside world – the site of a project, street life in front of the door, people, a significant place in the city. They express the need to forge and maintain connections between materials and places. These connections may be of varying nature and quality: chronological, narrative, driven by the desire to contrast and confront. In many projects, students present remote places in the studio. This student reviews her trip to Ghana where after observing and recording a place she would put up a red carpet watching how this intervention changed the place and people's behaviour (Figure 9).

The notion of 'multiple travelling' refers to the fact that students often repeat their journey in the studio when they review the collected material again and again, with different layers and aspects coming to the surface. Students used and adapted the projection set-ups we provided for recreating aspects of a remote place. Like in this example of a student group who arranged seats like in the underground with passengers that had to stand being provided with a handle made from orange plastic. In this configuration they re visited their trip to the Stade de France (Figure 10). Students recreated aspects of remote sites. Using projection screens and hanging posters they modelled the form and disposition of architectural elements.

Configuring. At the beginning of a project, students set up their workspaces, which grow over time. They are dense with design material, which is exhibited on the surrounding walls and on parts of the desk space. Sketches, plans, model, a

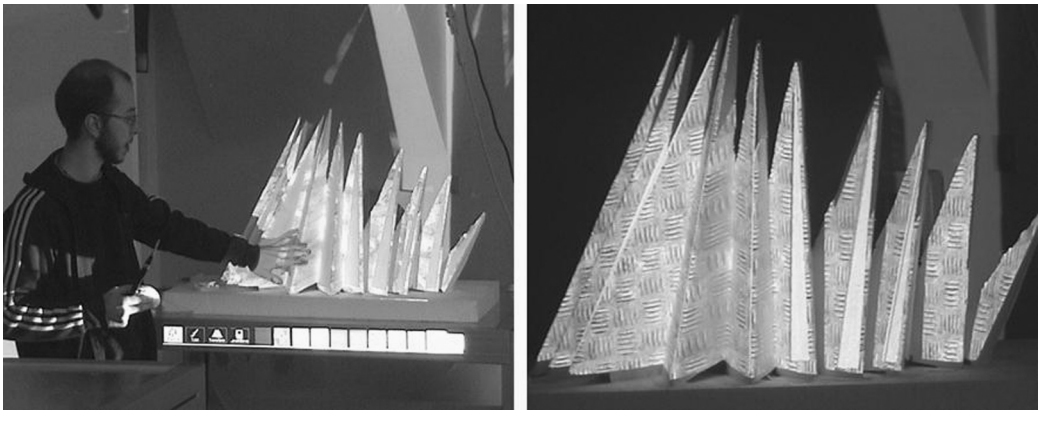

Figure 8. 3D table, in the right corner a physical model with a virtual tree

panorama print of a site, and the computer, are all assembled in one desk space. Students express a strong need for configuring 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. In architecture the backstage and the garage stand for such spaces in which everything is possible. One of our interventions in the physical space is the grid (Figure 11). The grid that was installed in the Interaction Design Studio measured 6x6 meters and was fastened to the ceiling. Things hanging from above could be attached to it. A set of spotlights (18 overall, evenly distributed) was fixed on the rails. The lights could be controlled by an easy-to-use light board. The system provided means for isolating smaller partitions of the room to be used for smaller groups.

More importantly, it supported students in furnishing their project spaces in whatever way they wanted and in rearranging them whenever activities changed. These arrangements could be performed in a varied topography in the space, with the possibility to experience things from above or below. Another thing achieved with the grid was that it could be used as a "back stage", having cables and wires being attached from above, thus keeping at least the floor wireless. The students used the grid and projection/light facilities to reconfigure their workplace in accordance with the activities they were carrying out. Moreover, introducing tagged cards and readers enabled them to set up workplaces without the ordinary desktop computer. They turned out to make creative use of the space for different projections, projecting visual output literally anywhere in space (Figure 12). By masking the projector lens students could even project on round or curved surfaces. Arrangements for placing projectors in different directions and angles were supported by the grid. A fairly large amount of different material provided building blocks for suitable non-traditional screens. One benefit of freely arranging displays is that it gives the possibility to suggest social interaction within the space.

One of the student groups created

Figure 9: The Ghana trip - multiple travelling

Figure 11. A varied topography– to see from above and below.

Figure 10. The ride in the metro

Figure 12. Projecting video on any object by using the grid.

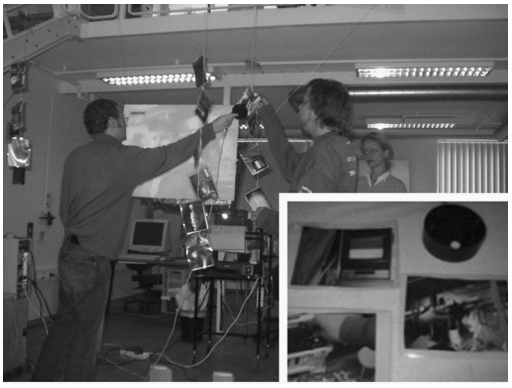

Figure 13. Spatial collages – a collaborative workspace

spatial collages by attaching media to tagged cards, which they suspended to the grid. Having the 3D collages around was inspirational, but also made the material available in quite another way than having to go to a PC workstation, boot the computer, find the right software, and browse for the right file. The surrounding space for the students turned into one telling different stories about actual places. Entering the studio enabled anyone to take part in the stories (Figure 13).

The students built different stages for enacting design in the same space where the other work was carried out (Figure 14). These full scale mock-ups of an environment provided the possibility for several actors to perform at the same time and a natural way of expressing interaction by placing a mock-up of the design artifact in the scene.

3 Discussion

The examples we provided show different ways in which qualities of the learning environment can be concretized integrating digital media and interactivity using space and material artifacts. In particular we showed ways of extending artifacts and using the space as a configurable stage to explore and experience situations.

Figure 14. Building stages for enacting design

3.1 Extending physical artifacts

Our objective in integrating computing in artifacts and in the environment was to maintain and support specific qualities of the learning environment: materiality and the diversity of materials and representations as well as re-programming and the 'different view'. In contrast to what has been designed and explored before, we make use of students' 'natural' learning environment instead of creating sophisticated dedicated objects (e.g. the 'magic carpet', Stanton et al. 2001; pawns for creating interactive stories, Mazalek, Davenport, et al. 2002). The settings we considered are characterized by evolving environments – students configure and re-configure their workspaces, they adapt them to different uses and identities. Moreover, students' field of work is highly complex and they constantly invent and probe techniques for representing this complexity. As a consequence, the design artifacts they produce evolve and are changing. Finally, what is inspiring and meaningful for the students, depends on context. Objects or a place, for example, are not inspirational as such but may be so in connection with a specific project, idea or particular task.

Animating Artifacts. Students used the prototypes in several ways: they animated physical artifacts, also creating new representational formats, and they produced. Barcodes and sensors on diagrams or models, objects with embedded RFID tags (spatial collages) where different cards represent

different aspects of a workplace, are all examples of ways to animate the environment (playing media). They help keep physical design representations in their materiality at the core of students' interactions. They enrich these artifacts by making multiple perspectives, readings, and connections visible. The latter reflects an important aspect of learning environments, that of mediating concepts between students and teachers. By maintaining different perspectives onto a design artifact or scenario, storytelling is supported and narrative elements can blend with others such as functionality or mere descriptions.

Mixed objects. On the other hand the Texture Brush allowed painting virtual textures on physical models creating what De Michelis calls mixed objects (2004). This approach goes beyond simply enriching a physical artifact by linking it with content in different media. In this case the link is such that the properties of the artifact itself can be changed, by applying colour, inserting movement and context, and varying its dimension in relation to other objects in the physical space. A characteristic of these animated or mixed objects is that you have to interact to experience them. By integrating barcodes into a drawing, for example, a student created a new way of engaging with the design artifact. The diagram does not speak for itself - you have to physically interact with it.

3.2 Using the space as a stage

The ways the students used the physical environment addressed in particular two qualities: maintaining and forging connections – multiple travels and configurability. The prototypes helped students explore the performative elements of space, experiment with scale and immersiveness, including unusual perspectives onto objects or a space, and create mixed spaces.

The performative elements of space. An 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 Bernard Tschumi's idea of "architecture not as an object (or work, in structuralist terms), but as an 'interaction of space and events'" (Tschumi 1977). The performative aspects of space address how a situation must be considered as a whole, which is of great importance in deign of interactive systems and spaces. 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. Elements of performance or experience of an installation is valuable complements to working with more abstract mental models of representation.

Performance artist Ulay refers to the space in which he performs as "edited life" or "choreographed existence". While using the same body that sleeps, makes loves etc., it's also a matter of stepping out of the ordinary body and into the performance body. This stepping into a "mental physical space" was of utmost importance to him and his partner Marina Abrimovic (Pejic 1998). This might be similar to how a designer can step into a semi-real space that resembles everyday life, but leaves no constraints for imaginative acting. To enact design concepts in performed scenarios brings forth situations where designers relate to technology with strong presence of the body. To have the body as reference to space or a situation of use brings forth a perceptual presence to the model or situation that also addresses tacit dimensions of user reality. It both addresses needs for intuitive evaluation that does not have to be verbalized and raises questions beyond mere

functionality. Working with scenarios in this way is reflective, since it explicitly engages with the user environment. At the same time it is experimental in the way it supports imagination of future activities. One group used this opportunity for negotiating the social interaction that can take place in a driver's cabin and what kind of design that could support such interaction (Figure 14).

Scale and immersiveness. As illustrated in our fieldwork examples, scale and immersiveness are major issues in both areas, architecture and interaction design. In interaction design it enables students to enact a scene/use situation in a life size environment. Architects always work with representations of what may be built in different scale. They may for example carry their models to the site, looking into them with an endoscope. This helps them imagine the design in a life size environment. Scaling may help discover new features of a material or a site, experience how a model or texture looks like when it is blown up. Real size is to do with bodily presence. It is not scale in the geometric sense that matters but immersiveness and realism. Immersiveness can be obtained with simple means, using several beamers and projection screens, "projecting everywhere". For architects it is important that projections reach down onto the floor, filling in the edge between wall and floor. Another issue is the unusual view onto a model or scene, using the (web)camera as an artificial eye fixed in unusual positions. Moreover, the web cams can be used for recording changes made to the space or to a model

Mixed spaces: Grid, projection set-ups, Texture Brush can be configured so as to produce mixed spaces. One interesting aspect of this mixing of the physical and digital is the transient and ephemeral way in which artifacts, people, and ambiences are encountered. This resonates with what architects see as an important aspect of their work – the peripheral presence of events or objects, with short time events, fast, assembled, ad-hoc, such as film, video and fashion photography being important inspirational resources (Wagner 2002).

3.3 Summary

We described several episodes, which, despite their variety and uniqueness, contribute to support our view of the environment as a whole characterized by key qualities. The material on which we base our argumentation has been collected in two different learning settings with common characteristics - space and activities undergo constant reorganizations and they are rich with artifacts of different materiality. Although the settings are specific, we consider them as representative of project-based learning environments. Student and teaching staff were not merely users but had an active role in shaping the technologies and in integrating them into their work setting. The results of this cooperative development are installations, which help understand some salient issues of tangible computing. Our paper focuses on two design themes:

1) The focus on mixing physical artifacts and digital media allowed us to show how technology can be used for extending physical artifacts to animated artifacts or mixed objects and increased our understanding of augmented reality strategies concerning objects. In collaborative work they can be shared across different perspectives and interests. Being objective for change, by manipulating both the physical body and digital properties, they support student's need for perceiving them differently in different phases of design.

2) The focus on connecting, configuring, and integrating the physical space brought to create stages to experience and explore aspects of remote places, situations, scale and immersiveness. Acting and working in these spaces can increase the perception of places intended for design as being a whole. Not only focusing on a device for interaction

or an architectural component, but on the rich interplay between spaces, artifacts and social communication.

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