Please quote as: Huang, J., Cherubini, M., Nova, N., and Dillenbourg, P. Interactive Furniture Supporting Collaboration. CSCL Series. Springer-Verlag, London, UK, 2008, ch. Introduction: Why Would Furniture Be Relevant For Collaborative Learning? , pp. 1–15.

INTRODUCTION

WHY WOULD FURNITURE BE RELEVANT FOR COLLABORATIVE LEARNING?

J. Huang, M. Cherubini, N. Nova & P. Dillenbourg

This books presents research into "collaborative artifacts and interactive furniture," (CAIF) i.e. interfaces embedded in everyday objects, such as tables, chairs, lamps, especially with a view to support collaborative learning.

For the first two decades since the birth of the personal computer, the development of hardware has been driven by the vision of "bringing a computer to every desktop" expressed by Bill Gates, founder of Microsoft, in the late 1970s. Following this vision, hardware designers and computer manufactures ordinarily constrained the form of computing to standardized flat or tower (often beige) boxes, suitable for placement on every desktop, and serving the primary function of running a wide variety of desktop software applications. In the 1990s, a trend towards miniaturization meant that smaller devices emerged, including notebooks, laptops, PDAs and other hand-held mobile devices. The advent of cell phones and mobile Internet has also led to the "mobile learning" paradigm, namely systems that engage in learning across contexts and learning with mobile devices. Recently, there has been a new shift towards what is called "roomware" (Streitz et al., 1998): the integration of technologies into everyday artifacts, ranging from tables to walls or kitchen furniture, with interactive tables and tabletops being a particular focal point for such efforts. Roomware appears as a parallel track of research to mobile learning that sometimes that sometimes has complementary affordances; the phone can, for example, be employed as a means of inputting data to interact with furniture or interactive architectures.

Within the Computer Supported Collaborative Learning (CSCL) and the Ubiquitous computing (Ubicomp) community, interest in this trend towards embedding collaborative technologies into furniture is growing. Researchers explore the elements that make up interactive spaces and the role of interactive, and effects these spaces have on collaboration. Different approaches have been implemented to support group work with adapted office spaces and room elements, but so far, at this early stage of development, none of these approaches alone offers a consistent solution to the question of how to integrate technologies in objects and environments in a way to support collaboration.

The present book is a compilation of papers presented in a workshop called "Collaborative Artifacts Interactive Furniture" that we organized in Château d'Oex, Switzerland, in June 2005[1]. Our motivation for this workshop was to bring together researchers, architects, psychologists, and computer scientists interested in collaboration and how new kinds of environments can support it. It aimed at sharing experiences and discussing research results in this area with the ultimate goal of defining emergent research questions and future research directions. A secondary motivation was a new project being planned on our campus: the construction of the EPFL Rolex Learning Center[2]. One of the Learning Center's main objectives is to optimize access to information by providing the necessary infrastructure, services and skills to the academic community. This new building provided a concrete application platform for thinking about, testing and put into action some of the interactive furniture and collaborative artifacts discussed here, serving as a reality check for our conversations.

1.1 Interactive furniture

There are various reasons for the surging interest in augmented interactive furniture in conjunction with collaboration and collaborative learning.

The first reason is that it is a general trend in the larger research area of human-computer interaction (HCI), in which area computer supported work and learning is situated. The new sub area typically referred to as "ubiquitous" or "pervasive" computing is a logical extension of HCI research, once it has moved beyond the desktop. Research in this area is derived from recent advancements in three interrelated fields: tangible user interfaces (which involves explicit contact with hands and bodies as described in Ullmer and Ishii 1997), ubiquitous computing (in which one person have multiple devices available in his or her environment and computational power is available everywhere as envisioned by Weiser in 1991) and augmented reality (the result of overlaying and adding digital information to real objects or integrating computational power into them as described in Feiner et al., 1993).

[1] Workshop website: http://craftsrv1.epfl.ch/~cherubini/caif , last accessed March 2008.
[2] Project website: http://learningcenter.epfl.ch/, last accessed April 2008.

The general promise at the convergence of these three areas is that by building tangible interaction environments with ubiquitous computing facilities that adapt to the needs of the people working in them, we might enhance, augment, and facilitate more natural interaction within face-to-face collaboration. The rationale is to move beyond the desktop computing paradigm with more natural affordances: table or wall interactions are more intuitive and direct as opposed to the desktop metaphor.

A second reason coming from the professional community is that this paradigm shift in human-computer interaction opens up new areas for engineers and designers to either develop new artifacts or augment existing ones. In this context, furniture, as everyday objects, is a natural candidate for interactivity. Furniture is flexible, omnipresent, socially already adapted and integrated. Moreover, the roles of furniture and operations in different contexts are well understood, at least intuitively. In this paradigm, the computer disappears and objects take advantage of computational capabilities to support new usage scenarios. This has the following implications on design practice: artifacts in the world are becoming interfaces for information spaces and collaboration among people. This is a shift from seeing objects and furniture as containers or pedestals for computing, to a view of furniture as communication vectors. Along the same lines, the rooms where interactive furniture is located are being transformed, since computing affects not only the objects themselves but also what happens between and among them. Architects and interior designers are asking: what is the role of rooms in the emerging society of interactive furniture? This merger of software, hardware and rooms leads to collaboration between space designers and information technology researchers in a new a research area where the design and the evaluation of computer-augmented room elements like walls, furniture, tables and chairs with integrated information and communication technology are explored.

Finally, a third, psychological, reason for the rising interest in interactive furniture links interactive furniture cognitively to spatial organization and co-presence. Furniture has important affordances: objects, tools and information on a table/wall have a specific organization. Human beings organize information spatially so as to simplify perception and choice (Kirsh, 1995), or they modify their environments to help them solve problems (Kirsh & Maglio, 1994). The spatial environment is hence used as an external representation employed to solve the problem they are working on. The location of artifacts in the environments is an important source of information (e.g. Dix et al, 1993). By their positions, orientations, and movement, artifacts can show the state of people's interaction with them. For example, the observatory work of traditional tabletop collaboration described by Scott et al. (2004) has shown how collaborators have different sorts of "territories". They indeed found that participants employed three types of tabletop territories to help coordinate their interactions within the shared tabletop workspace: personal, group, and storage territories. In the context of collaboration, furniture is particularly well suited to supporting collocated collaboration and providing a means of indicating co-presence. According to researchers, co-presence matters for:

(1) Having a feeling of presence (Lombard & Dilton, 1997). Co- presence is thus the psychological sense of "being together" in such an environment. It can be

defined as a form of human co-location where the participants can see each other. Co-presence is the cornerstone of collaboration since it is the subjective experience of being together with other participants and building trust between people.

(2) Carrying out joint activities through awareness of others' reactions: the effect of close proximity in work settings is that it helps maintaining task and group awareness

(3) Monitoring eye gazes: Mutual gaze plays a powerful role in face-to-face conversation: regulating the conversation flow, monitoring if the addressee has understood what the contributor meant, communicating facially evident emotion, communicating the nature of the interpersonal relationship, communicating the status, preventing distraction and information overload, signaling interest and attention and coordinating turn-taking during the interaction (Argyle & Cook, 1976).

Furniture elements (be they interactive or not) are hence thought of as pertinent artifacts in supporting collaborative interactions through the augmentation of the co-present phenomena described above.

1.2 Collaborative Learning

This book belongs to a series entitled "computer-supported collaborative learning" (CSCL). However, the interactive furniture elements presented in this book are quite different from the environments usually referred to in CSCL such as on-line forums or shared simulations. To elaborate about the relevance of these artifacts for CSCL, let us analyze the four words that compose this title.

The first part of this introduction carries a specific message regarding to the first "C" of CSCL, which refers to computers. This book illustrates the fact that technologies for educational practices are not only these ugly boxes that we refer to as computers, but a variety of artifacts enhanced with digital technologies, an evolution of CSCL that has been initiated by Ulrich Hoppe (chapter 3). We should indeed refer to "computing" instead of "computers" to cover the range of artifacts now being investigated as means of supporting collaborative learning.

As a result, the readers may wonder about the "L" of CSCL: most technologies reported here could fit in living rooms, office or bars more easily than in traditional classrooms. We did not want to restrict the workshop or the book to a narrow educational definition. Except in chapters 1 and 3, the relevance of the different artifacts for supporting learning is far from obvious. This is not an accidental drift in the scope of the series, but instead an intentional move: we hypothesize that technologies that do not have an obvious educational intent might actually have a greater chances of being adopted for classrooms than those that are obviously designed for school practices. Let us consider teachers in western European schools. They book low cost airline tickets or concert tickets on the Internet simply because it is the only way to do it. They upload their holiday photos on the computers and share them with friends over the Internet. They exchange SMS and download music for their MP3 players. In other words, they cope well with our technology-rich environment until… it comes to using computers for teaching. As soon as we address educational computing, they often explain the various practical constraints that justify why they use computers more outside the classroom than inside. We reached the point where the low deployment of learning technologies cannot simply be explained by the teachers' lack of computer skills. What would be alternative explanations for the fact that technologies are still moderately exploited in classrooms while they re pervasive outside classrooms? One explanation – among others- could be that the educational label attached to e-learning environments, questions the teachers' role. If the designer starts with the question "how could a computer support the learning process," the designed software or environment will inevitably interfere with the activities the teacher is supposed to carry out. Even if his interference is supposed to be positive, i.e. if it helps teachers trigger learning mechanisms, the new software or environment redefines of the educator's role. Other innovative technologies that do not have any educational terms in their names, such as sticky notes, CD players or digital cameras, do not encounter similar resistance. These informal observations raised the hypothesis that technologies with an educational label are more easily adopted by teachers than those that have an explicit educational function. Let us admit that this is only a wild hypothesis and that we are far from having a strong empirical evidence for it.

A more pragmatic question regarding to the "L" of CSCL is whether the type of interactive furniture presented in this book will ever enter into learning places. The answer varies according to the educational context. In Switzerland, primary schools actually have a diverse geographical structure that often includes 5 zones: the standard table and chairs area, a more open area in front of the whiteboard where kids may sit on the ground for informal but collective activities (e.g. reporting their week-end story), a corner with a sofa or pillows where they can borrow and read books, a corner with a computer and finally an area where kids store and retrieve exercises sheets for their individualized work plan. This rich and diverse environment offers multiple opportunities for innovative pieces of furniture and requires that type of spatial flexibility that Lahlou addresses in chapter 4. At the other end of the educational chain, many universities complement their traditional lecturing theatres with rooms where students may work individually or in teams, as well as enjoying life (e.g., watching a movie using the available projectors). We mentioned that fact that our university (EPFL) is constructing an ambitious learning centre: since it takes several years to build such a centre, we had to create multiple smaller learning places in the interim to accommodate an urgent need for places purposely designed for team learning. Similar needs have also emerged in corporate training. These dedicated workplaces offer many opportunities for the type of innovative furniture presented in this book. The time structure and the curriculum of secondary education does not seem to provide the same range of opportunities that primary and tertiary education do for interactive technologies.

Let us now consider the second "C" of CSCL, which stands for "collaborative". It is interesting to notice that in the label "CSCW", the second "C" stands for "cooperative". There is no point here in arguing long about the difference between these words in terms of division of labor (Dillenbourg, 1999). The key point here is that empirical studies have shown that positive learning outcomes do not result simply because students are asked to collaborate or to cooperate. Learning occurs to the extent to which students engage into rich verbal interactions such as the co-construction of elaborated explanations, the resolution of epistemic conflicts through argumentation and negotiation of meanings and the elicitation of mutual regulation processes. Hence, the main purpose of CSCL technologies is not necessarily what is usually presented as collaboration (mainly coordination) functionalities (e.g. awareness tools, dialogue history), but the fact that they favor the emergence of interactions that are known to produce learning. The range of artifacts presented in this book are not all "collaborative" in the strictest sense of the term, but they do have in common is that they each create some kind of affordances for social interactions. Do the tables and other artifacts presented favor any kind of social interactions, or do they specifically foster the categories of verbal interaction that generate knowledge (explanation, argumentation, regulation)? This question leads us to analyze the "S" of CSCL, by asking how does technology shapes social interaction in a favorable way?

For a subset of CSCL environments, the "S" actually means an "M": the computer supports collaboration simply because it enables on-line communication at a distance as in 'computer-mediated communication'. This book addresses co-present teamwork, not remote collaboration. This is not new for the field of CSCL where some of initial work of Roschelle (1992) on physics simulations or Suthers on graphical argumentation (Suthers et al., 1995) was about co-present collaboration. However, in these CSCL applications, even if the students are sitting next to each other, the technology was only concerned by their interaction within a digital representation or virtual space on the computer display. The physicality of co-presence was not integrated in the design of such environments. It was introduced in CSCL by scholars working on multiple-input devices, such as computers with two mice (Inkpen et al, 1999) or single-display groupware (Zanella & Greenberg, 2001). This book goes one step further in considering the physicality of collaborative work. It addresses the affordances and constraints of the physical space in which students learn together, not only in their immediate interactions with artifacts or between students, but also with the surrounding space.

In current CSCL environments, the "S" is often interpreted as "scaffolding," – the fact that the technology will favor the emergence of rich social interactions. "Favor" covers a range of more or less intrusive ways ranging from interface cues (e.g. a graphical palette that includes a "counter-evidence" box) to direct prompts (e.g. "Please provide counter-evidence to the claims made by your partner") and learning scenarios or scripts (Dillenbourg & Jermann, 2007). This book clearly focuses on the less intrusive, less didactic ways of shaping social interactions, although the Reflect table (this volume, chapter 2) nonetheless conveys a rather normative model of what effective collaboration should be.

In summary, two decades of CSCL research have led to one key lesson: collaboration can be "designed," and team processes shaped by the software tools used by the team. This lesson is extended in this book by the fact that interactions are also influenced by hardware, by the physicality of interacting with artifacts as well as the spatial properties of the immediate surroundings.

1.3 Precedents

Prior to “roomware” and the introduction of digital technologies into the world of furniture and objects, the idea of “augmenting” furniture through interactivity was already present in ancient history, in the practices of traditional furniture makers, and has been an integral part of furniture design. Indeed, the existence of augmented furniture in which the interactive component goes beyond common affordances, e.g. opening and closing a door or drawer, or changing the height of table legs, can be traced back across different times and cultures.

Examples of furniture where the interactive component has become integral part of the very furniture type (and not merely of some instances of a furniture type) include the French “secrétaire,” the British “maritime desk,” or the American “lazy susan”.

The French secrétaire is high-standing hybrid furniture originally created in the 16th century as a salon piece for writing letters and journals that can morph from an armoire to a desk. The furniture includes multiple drawers for stationary and documents, and, as the name suggests, features one or multiple “secret” compartments, which, depending on the skills and ingenuity of the furniture maker, were more or less well hidden, and only accessible through the exact performance of a combination of interactive movements such as lifting, pulling and sliding.

A different category of furniture uses interactivity not to hide objects but to make the furniture itself more adaptable. Examples of this type of augmented furniture include maritime furniture used by sea captains of the British fleet: lightweight yet weatherproof mahogany desks and cabinets, easily foldable, and reconfigurable, ideally suited to accommodate the captains’ lifestyles which were often divided between land and sea. Furniture had to be transportable and rapidly configurable for different (usually tight) spaces.

Yet another type of interactive furniture was developed to enhance sharing. A good example in this category is the “lazy susan” whose invention is generally attributed to Thomas Jefferson around 1800. The lazy susan, a rotating tray placed on top of a table, augments the table by giving it an interactive turning platform, helping users to share and move food and condiments around.

These examples augment furniture mechanically, and serve as precedents to the digitally augmented interactive furniture discussed here.

1.4 Interactive furniture framework

Researchers have approached the topic of interactive furniture from different points of view. Research foci range from the development of basic technologies and software platforms for building interactive furniture to application of the technologies in real settings and usage studies of interactive furniture in different environments. The types of furniture investigated vary. Here we propose how the different variations could be classified.

The variation of existing interactive furniture types can be roughly classified along three dimensions: geography of interaction (where), input/output (how), and purpose (what for).

1.5 Geography of interactions

There is a long list of built interactive furniture examples, ranging from tables, walls, chairs, curtains, and picture frames. A preliminary way to organize interactive furniture types is along their geographical context or where they are employed in space. Where in architectural space is the furniture located? This question can be further broken down into how the furniture is oriented. For example, is there a difference in horizontality and verticality as in. a tabletop or an interactive wall? Researchers have discussed the differences between a horizontal and a vertical surface with regards to what would be preferable for supporting collaboration (Shen, 2004). Each orientation has its own advantages and drawbacks and encourages different types of collaborative interaction. For example, Rogers and Lindley (2004) showed how people can work more collaboratively when seated next to each other as opposed to standing. Another consideration tied to orientation is the interaction or viewing angle: when people stand or sit at different positions around a horizontal display they will be viewing the contents from different angles. The classical problem occurs when two people are seating opposite each other and operate on the same, shared textual document. One of the participants will inevitably be obliged to read the document upside down (See also Streitz et al., 2001 and Tandler et al., 2001). This problem is often solved by specific software that "reorients" objects so that a given individual can view the content the right way (Shen, this volume chapter 5). Kruger et al. (2004), however, have argued how this software solution may be too simplistic because the orientation of objects has specific affordances and "proves critical to how individuals comprehend information, how collaborators coordinate their actions, and how they mediate communication. The coordinating role of orientation is evident in how people establish personal and group spaces and how they signal ownership of objects. In terms of communication, orientation is useful in initiating communicative exchanges and in continuing to speak to individuals about particular objects and work patterns as collaboration progresses…"

What is also interesting about geographical context is the combined use of various devices that connect a personal interface (the desktop or one interactive table) to multiple devices distributed in space: the geographic fragmentation of interaction. The simplest example is the combination of one table plus laptops, PDA and augmented objects (with RFID for example).

This is the case in the UbiTable developed by Mitsubishi Electronic Research Lab, described in chapter 5: users can walk up to the UbiTable and connect laptops, cameras, and other USB devices to the table to share, manipulate, exchange, and mark up their contents with each other on a large tabletop surface. At the same time, each user can still maintain explicit control over the accessibility and interactability of his/her own documents displayed on the tabletop.

The geographic position of the furniture also has an effect on the level of attention required. Furniture that attracts little attention (or now commonly known as ambient furniture) is placed at the periphery of the user's daily flow of activities (e.g. a clock), furniture that demands a high level of attention (or immersive furniture) typically occupies the centre; they so to speak operate "in your face" (e.g., the doorbell). Some designers proposed the concept of 'informative art' as a way to integrate information visualization in the everyday human environment. "Interactive wallpaper" (Huang & Waldvogel, 2005) or the "Weather by Mondrian" project (Holmquist and Skog, 2003) are relevant examples. The Mondrian project used a composition similar to the style of an abstract painter, Piet Mondrian, to show current weather conditions in picture frames, geographically located high on the wall, where they do not demand a lot of attention and thus do not distract the user from his/her main activity while still providing information.

1.6 Input/Output

We can also look at interactive furniture by examining what their input and output is.

1.6.1 A. Input

Here we can distinguish between input of information into interactive furniture from other digital devices such as a laptop or PDA, through USB or Bluetooth connections, and input directly from human interaction. In the latter category, fall touch or multi-touch input interfaces which received increased attention recently with Jef Han's multi-touch table[3] and Microsoft's Surface interface[4]. Tangible input existed in several custom products before, such as in the Onomy Tilty Table, designed by Onomy Labs, in Menlo Park, California. The Tilty Table was designed for specific interactions in museum settings, and uses, as the name suggests, a tilting interface. Images on the screen move when the table is tilted, as though some imaginary gravity force pulled them down. Other senses have been employed as input with a view to make interaction more natural. Acoustical interfaces have had an especially long research trajectory, yet the perfect text recognition interface seems still elusive. More playful interactive tables that deploy acoustical input exist, however. Examples of playful acoustical interfaces include musical furniture, such as Onomy's drumming table where the common drumming-on-the-edge-of-a-table gesture is converted into something more musical (Back et al. 2001), or noise-sensitive tables, where the table acts as a mirror reflecting the dynamics of a group conversation by visually discriminating the contribution of individual group members in discussions around the table (see chapter 2).

[3] http://cs.nyu.edu/~jhan/ftirtouch/index.html, last accessed March 2008.
[4] http://www.microsoft.com/surface, last accessed March 2008.

1.6.2 B. Output

The most frequent output interfaces in interactive furniture are probably high-resolution displays (VGA or XGA) using integrated LCD/DLP projectors, or flat screens (LCD or plasma screens). The degree of embeddedness (the level at which the output is integrated into the furniture) is an interesting differentiation factor, ranging from low embeddedness (e.g. a LCD screen placed on top of an existing table) to a complete symbiosis of output device and furniture. An example for the latter can be found in MIT Media Lab's CounterActive project (Selker 2003). The project focuses on interactive furniture in the kitchen. A computer, stored under the counter, is connected to a projector over the kitchen doorway that projects a tri-part image onto a portion of the kitchen counter. It can show step-by-step recipe instructions, playing the steps aloud and with images and videos. The project combines visual output with sound output. Other projects focus on audio output only. An early example is Laurie Anderson's "handphone table" which allows people to listen to sounds by putting their elbows on the table and covering their ears with their hands. In this example, bone conduction allows the conveyance of sounds

Between the input and output variations, there are, as one can imagine, almost limitless combinatorial possibilities. An interesting example that elegantly exploits combinatorial opportunities is the "Reactable" designed at the Music Technology Group UPF in Barcelona.

The Reactable combines tangible input (moving and rotating physical objects on a table) with audio output to generate music. This interactive furniture was successfully used by the popular artist Bjork as an instrument during her "Volta" tour in 2007.

1.7 Purpose

Finally, interactive furniture can be categorized according to what their purpose is. Typical purposes for interactive furniture includes brainstorming, negotiation, document sharing (text documents or sharing and sorting photos), information visualization, and background awareness. Furniture can also enable new functions rather than only supporting existing ones. An interactive table developed by FX PAL enables the storing and sharing of digital documents with participants' mobile devices (Chiu et al. 2007). The noise-sensitive table (chapter 2) augments collaboration through group involvement features such as the social mirroring of the group activity and tools to regulate and structure turn taking.

Furniture can also allow the inclusion of new users, as in furniture that enables remote participation in an interaction. The interactivity of the furniture is then meant to augment remote collaboration by allowing a mix of the digital and the physical space.

Clearly, interactive furniture is being developed along exciting dimensions, for different geographic contexts, using different input and output modalities, and for different purposes. Yet outside of research labs, interactive furniture is rarely seen or used. Why? The inflexibility of interactive furniture may be one of the reasons that would explain this situation: input interaction techniques can be too specific to let the table be used in other contexts, orientation issues of documents are often problematic as is the control of interactive features (display control, data inputs).

The integration of existing artifacts (PDA, cell phones) into furniture is often difficult and requires the use of additional systems and software. In addition, one of the general difficulties of roomware is that it generally requires users to adjust their practices Therefore, it will take some time to develop new habits of use for interactive furniture. Yet over three thousand years of furniture history[5], this transitional period of a couple of years that the use of digitally enhanced interactive furniture appears to be negligible. We are in a transitional period, at the very beginning of discovering what the real opportunities, affordances and dangers of interactive furniture might be, and we hope with this initial compilation to give a snapshot of the current research in this field, and provide a platform for future work.

1.8 Book overview

The essays collected in this book have been selected from workshop presentations. They cover different aspects regarding the design and use of interactive furniture in conjunction with collaboration support.

In the first chapter, Masanori Sugimoto presents three systems to support collaborative learning in an elementary school. The core idea of these interactive table applications is to enhance face-to-face interaction through the physical manipulation of objects. The paper describes the various steps in the design process, from determining learning requirements to different design iterations.

The second chapter, by the EPFL team, develops a design framework that articulates a model of self-regulation in collaborative learning with the design of a noise-sensitive table that displays interaction patterns.

The third chapter about collaborative learning, by Ulrich Hoppe, is an account of how the disappearing computer propelled by ubiquitous computing technologies leads to “integrated classrooms,” which eventually enable new production of learning material. Hoppe articulates his visions and the problem about such an approach based on his experience in an integrated classroom.

In chapter 4, Saadi Lahlou presents empirical studies conducted within an energy provider company in order to augment meetings. They were using shared interactive boards and videoconferencing systems embedded in walls and on mobile trolleys. The next chapter, by Maribeth Back et al. shows how a conference room podium could be augmented for supporting different interaction tasks, including authoring, presenting, and supporting telepresence. In the next chapter, Chia Shen describes the main issues regarding the design of collaborative tabletop applications through prototypes developed at Mitsubishi Electric Research Labs. She raises the issue that direct-touch tables are an emerging but immature user interface.

This book ends by two chapters with a stronger methodological emphasis. The paper by Haué & Dillenbourg reports an empirical study of people working around a table with their laptops. It illustrates the complementarity of qualitative and

[5] See http://en.wikipedia.org/wiki/Furniture, last accessed May 2008.

quantitative methods. In the last chapter, Lira Nikolovska and Edith Ackermann raise the importance of taking into account the physical, relational and cultural qualities of the objects to be augmented as “interactive furniture”. They speculate about the need to use new design methods through two examples, exploring the poetics of everyday objects.

1.9 Synthesis

This book does not provide a synthetic account of how interactive furniture might enhance collaborative learning. On the one hand, the picture is still fragmentary and lack of empirical evidence. On the other hand, it opens a different way to think about the role of technologies for supporting collaborative learning. We strongly believe that, beyond the 'gadget' dimension of existing examples, this new role will initiate a paradigm shift in the field of technology-enhanced learning.

1.10 References

Argyle, M., and Cook, M. (1976) *Gaze and Mutual Gaze*. Cambridge: Cambridge University Press.

Back, M., Cohen, J., Gold, R., Harrison, S. and Minneman, S. (2001): Listen Reader: An Electronically Augmented Paper-Based Book. In: Beaudouin-Lafon, Michel and Jacob, Robert J. K. (eds.) *Proceedings of the ACM CHI 2001 Human Factors in Computing Systems Conference* March 31 - April 5, 2001, Seattle, Washington, USA. pp. 23-29.

Chiu P., Lertsithichai S., and Liu Q. Interaction Models for Multi-Display Slideshows. *Pervasive 2007* Invited Demo, May 13, 2007

Dillenbourg P. (1999) What do you mean by collaborative learning? In P. Dillenbourg (Ed.), *Collaborative-learning: Cognitive and computational approaches* (pp.1-19). Oxford: Elsevier.

Dillenbourg, P., & Jermann, P. (2007). Designing integrative scripts. In F. Fischer, H. Mandl, J. Haake & I. Kollar (Eds.), *Scripting Computer-Supported Collaborative Learning – Cognitive, Computational, and Educational Perspectives* (pp. 275-301). Computer-Supported Collaborative Learning Series, New York: Springer.

Dix, A., Finlay, J., Abowd, G., and Beale, R., (1993). *Human-Computer Interaction*, Prentice Hall.

Feiner, S., MacIntyre, B., Seligmann, D. (1993). Knowledge-Based Augmented Reality. *Communication of ACM*, 36(7):53–62.

Holmquist, L.E. and Skog, T. (2003) Informative Art: Information Visualization in Everyday Environments. *Proceedings 1st International Conference on Computer Graphics and Interactive Techniques in Australia and Southeast Asia* (2003), 229-235.

Huang, J., and Waldvogel, M., (2005), Interactive Wallpaper, in *SIGGRAPH Electronic Arts and Animation Catalog (EAAC), SIGGRAPH 2005*, Los Angeles.

Inkpen, K., Ho-Ching, W., Kuederle, O., Scott, S.D., & Shoemaker, G. (1999) This is fun! We're all best friends and we're all playing.: Supporting children's synchronous collaboration. *Proceedings of CSCL*, Stanford, pp. 252—259

Ishii, H. and Ullmer, B., Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms, in *Proceedings of Conference on Human Factors in Computing Systems CHI '97*, (Atlanta, March 1997), ACM Press, pp. 234-241.

Karahalios, K. and T. Bergstrom (2006). Visualizing Audio in Group Table Conversation. *Proceedings of Horizontal Interactive Human-Computer Systems*, IEEE: 131-134, 2006.

Kirsh, D. & Maglio, P. (1994). On distinguish between epistemic from pragmatic action. *Cognitive Science*, 18, 513-549.

Kirsh, D. (1995). The Intelligent Use of Space. *Artificial Intelligence*, 73, (1-2), 31-68.

Kruger, R., Carpendale, M.S.T., Scott, S.D., and Greenberg, S. (2004). Roles of Orientation in Tabletop Collaboration: Comprehension, Coordination and Communication, *Journal on Computer Supported Cooperative Work*, 13(5-6), pp. 501-537, Kluwer Press.

Lombard, M. & Ditton, T. (1997). At the heart of it all: The concept of presence. *Journal of Mediated Communication*. 3 (2).
Rogers, Y. and Lindley, S. Collaborating Around Vertical and Horizontal Displays: Which Way is Best? *Interacting With Computers*; 16(4), December 2004, pp. 1133-1152.
Roschelle, J. (1992) Learning by Collaborating: Convergent Conceptual Change. *Journal of the Learning Sciences*, 2, 235-276.
Scott, S.D., Carpendale, M.S.T., and Inkpen, K.M. (2004). Territoriality in Collaborative Tabletop Workspaces. In *Proceedings of CSCW 2004*, 294–303.
Selker, T. (2003): Fostering Motivation and Creativity for Computer Users. In: *Proceedings of the Tenth International Conference on Human-Computer Interaction* 2003. pp. 1303-1307.
Shen, C., Vernier, F. D., Forlines, C. and Ringel, M. (2004): DiamondSpin: an extensible toolkit for around-the-table interaction. In: Dykstra-Erickson, Elizabeth and Tscheligi, Manfred (eds.) *Proceedings of ACM CHI 2004 Conference on Human Factors in Computing Systems*, April 24-29, 2004, Vienna, Austria. pp. 167-174.
Streitz, N., Geißler, J., Holmer, T. (1998). Roomware for Cooperative Buildings - Integrated design of architectural and information spaces. Streitz (ed.) *Proceedings of the International Workshop on Cooperative Buildings* (CoBuild'98). Springer, LNCS (1998).
Streitz, N., Tandler, P., Mller-Tomfelde, C., Konomi, S. (2001). Roomware: Towards the Next Generation of Human-Computer Interaction based on an Integrated Design of Real and Virtual Worlds. In J. A. Carroll (Ed.): *Human-Computer Interaction in the New Millenium*, Addison Wesley, pp. 551--576.
Suthers, D., Weiner, A. Connelly J. & Paolucci, M. (1995) Belvedere: Engaging students in critical discussion of science and public policy issues. In. J. Greer(Ed). *Proceedings of the International Conference in Artificial Intelligence in Education*, Washington, August 16-19, pp. 266-273.
Tandler P., Prante, T., Mller-Tomfelde, C., Streitz, N., Steinmetz, R., (2001). ConnecTables: Dynamic Coupling of Displays for the Flexible Creation of Shared Workspaces. In *Proceedings of the 14th Annual ACM Symposium on User Interface Software and Technology* (UIST'01), Orlando, Florida, USA, November 11-14, 2001, CHI Letters 3(2), ACM Press.
Weiser, M. (1991). The computer for the 21st century. *Scientific American*, 265, 3, 94–104.
Zanella, A. & Greenberg, S. (2001). Reducing interference in single display groupware through transparency. In *Proceedings of the Seventh Conference on European Conference on Computer Supported Cooperative Work* (Bonn, Germany, September 16 - 20, 2001). W. Prinz, M. Jarke, Y. Rogers, K. Schmidt, and V. Wulf, Eds. ECSCW. Kluwer Academic Publishers, Norwell, MA, 339-358.