Journal of Universal Computer Science, vol. 2, no. 10 (1996), 694-710
submitted: 15/10/96, accepted: 15/10/96, appeared: 28/10/96

Interdisciplinary Development of an Electronic Class and Conference Room

Max Mühlhäuser
(University of Linz, Austria
max@tk.uni-linz.ac.at)

Abstract: This paper reports on the design and development of an electronic classroom and conference room which was opened in the city of Linz, Austria, in late 1996. This room was developed in a multidisciplinary approach and contains several unique features. After an introduction about the background, rationale for merging the concepts of classroom and conference room, and an overview about the four layers of the logical architecture, the paper emphasizes issues associated with the facilities installed. Then the attention is drawn upon a "consumables" layer which we propose to insert between such facilities and the usual software tools. A brief overview of the tools and contents layers completes the description.

1. Introduction

1.1 Background

In September 1996, the Telecooperation Group at the University of Linz deployed the first version of CCF, a fully equipped facility to be used as both a classroom and a business meeting venue. CCF stands for *class / conference room of the future;* it is part of the Ars Electronica Center, an exhibition and activity venue located in the heart of Linz, capital of Upper Austria, a region which is considered one of the so-called motors of Europe. The experience gained during the planning and realization of CCF is of potential interest to other groups intending to set up or enhance learning or meeting facilities.

The integrated and interdisciplinary approach chosen is rather unique: the project involved close cooperation not only of vendors and university research, but also of architects, furniture designers, networking and multimedia specialists, pedagogical experts, and end users – teachers, learners, and users of meeting facilities. The Telecooperation Group of the University of Linz was chartered with the overall planning, project management, and core software development. For heading this project, the author could draw from over six years of experience with cooperative multimedia teaching concepts gained during the management of project Nestor [Mühlhäuser 95].

1.2 The Convergence of Class and Conference Rooms

The CCF design assumes that future learning facilities and future meeting facilities have much in common for the following reasons. Due to ever shorter innovation turnaround times and mass amounts of information produced, teachers will less than ever be able to master an up-to-date subject matter completely. The out-dated model of teachers being "vessels of knowledge" – pouring out their knowledge onto the learners – thus becomes completely unrealistic, the ubiquitous desire to overcome this model becomes a *must*. Teachers become mediators, coaching the learners during *their* knowledge acquisition, processing, and conveying activities. This new learning style, similar to creative business meetings, may foster many advantages:

- learners become more actively involved, a change which can raise their motivation, understanding, and retention;
- they learn to learn (to acquire and process knowledge) and even learn to 'teach' (convey the knowledge to fellow learners), thus acquiring skills which become ever more important in our work live and even private live;
- since the new learning is composed of phases of active learning and of mutual update, carried out in the net and with the help of computers, it can be easily integrated with advanced CSCL (computer-supported cooperative learning) approaches, implicitly teaching cooperative work to the learners and thus again providing skills which are in desperate need in modern societies.

Even in an open teleteaching setting where physical presence is not required, mutual encounters and close non-mediated communication will always remain important, so that a real, physically existing classroom will remain essential. It will also remain a hub for access to "the net", in average better equipped than individual workplaces.

It was argued above that the abilities to acquire, process, and convey knowledge in a networked setup represents a set of skills which are increasingly crucial for ones private and work live. This increasing importance is due to the new challenges in modern economies, in particular

- lean organizational structures (demanding cooperation and autonomous action) and
- global competition, markets, and ventures (on one hand demanding telecooperation, on the other hand requiring rapid adaptation to new developments, processes, approaches etc., i.e. requiring up-to-date acquisition and sharing of knowledge).

In this emerging business context, creative meetings play an important role. In such meetings, problems are structured and decomposed, learning-like steps are performed either on-line in the team or partly off-line (for instance by visiting a fair and reporting back to the team). While for some of the meetings, remote colleagues, experts, or educated teachers will join in over the net, the presence of a physical conference facility remains important (as argued for classrooms above). The value of physical encounter is not supposed to fade away even as telemeeting technology matures.

If classrooms and conference rooms (in the sense of meeting facilities) merge like this, mediated cooperative learning experiences at school can turn into live-long, just-in-time learning skills which are applied throughout live.

To summarize, we view the classroom of the future as a meeting facility where the roles of teacher and learner become blurred, where teams can access and acquire information electronically, communicate locally and remotely over the net, and process and share the knowledge gained in this process.

1.3 Overview

Figure 1 provides a brief overview of the four major layers of the CCF logical architecture, coined as *facilities*, *consumables*, *toolsets*, and *curricula*. These layers are reflected in the structure of this paper. The components shown in the figure represent only those ingredients which we identified as the most important ones. Even among these, we will in the remainder concentrate on the ones for which we believe that the rationale behind may be particular important for readers involved in comparable projects.

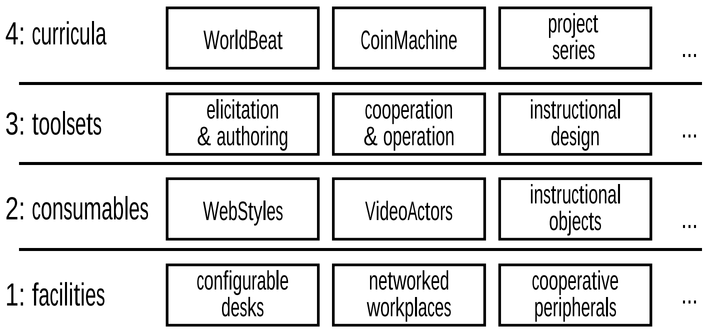

Figure 1: CCF Logical Architecture

2. The Facilities Layer

2.1 Overall Architecture and Interior Design

Room geometry and partitioning: The basic geometry of the CCF is a circle. Although this choice is believed to provide psychological backup for our emphasis on democratic, team-based working styles, there are of course many practical reasons for which other similar projects will want to adhere to the classical rectangular design. We would not advocate the circle as a crucial design decision. Figure 2 shows a photograph of the core CCF; since it was taken during the installation process, not all components are shown in their final version (e.g., CRT monitors are shown instead of LCDs, see 2.3).

Figure 3 shows the floor plan of the electronic classroom. This abstract floor drawing is taken from the explanation component of our management / operation software and thus contains the icons assigned to the different exhibits and parts of the floor. As the figure shows, there are a number of “rooms” adjoint to the CCF. Since we emphasized a very open overall setting, we did not separate them as truly closed rooms (apart from the server room and stock which are not shown here), but designed these parts as smaller and larger alcoves. Two of these alcoves are integrated with the CCF:

- The *multimedia studio*, conceived as the interface to the analog world. As long as analog media (by which we mean anything from written notes on paper to video cassettes) remain important, there will be a variety of equipment interfacing to this analog world, such as scanners, video encoders, audio digitizers, color printers etc. This equipment will hardly ever be affordable and often not even needed at every workplace. This is why we make it available in a separate alcove.
- The *extended living room*, deliberately conceived as the extreme alternative to an integrally designed CCF. The goal is to make learners feel comfortable, almost at home. Long-lasting discussions and privacy-demanding phases of thinking match badly with ergonomically designed yet “antiseptic” workplaces of a typical electronic classroom; for such working styles, we designed the extended living room, equipped with couches and armchairs, laptops, and a wall-mounted TV-like screen.

The alcoves in the CCF *atrium* represent special working styles that would not and do not require separate physical workplaces. Rather, these alcoves are a tribute to the role of the Ars Electronica Center as a museum of the future. They are accessible to the visitors even when classes or business meetings go on in the CCF (separated by glass doors), exhibiting a small excerpt of what can be done at a regular CCF workplace. At the same time, these exhibits can be viewed as example components of the other layers shown in Figure 1 and discussed later in the paper: VideoActors represent a consumable (layer 2, see 3.3), InteractiveTV contains, among others, a teletext-indexed news database which is an example of an elicitation tool (layer 3, see 4.1), and CoinMachine and WorldBeat convey information about novel approaches to curricula (layer 4, see 4.2).

Figure 2: Snapshot of the CCF (monitors will be replaced by LCDs)

2.2 Configurable Desks

The desks have been specially designed for the CCF. The basic features include: i) lockable wheels for quickly moving the desks between different configurations; ii) trapezoidal or rectangular shape, respectively, in order to fit all configurations; iii) lockable deskside PC rack, not interfering with leg movements; iv) a variety of ergonomic aspects such as movable keyboard / mouse drawer, fastenings for light, video camera, headset, etc. As these features suggest, a major design decision was the introduction of variable configurations. The desks can accommodate four plus one major setups:

- *Roundtable*, an oval (or circle, depending on the class size) intended for democratic instructional setups, where all participants shall have equal rank initially;
- *Taskforces,* up to three smaller groups (plus maybe groups working at the alcoves) configured in an arc shape around one of the "center-of-focus" devices (see 2.2).
- *Telepresence,* a U shaped configuration directly adjoining either the electronic wall (see 2.2) or an interactive electronic whiteboard. This configuration got its name from the intended use where a remote class or remote participant(s) are projected onto the wall or whiteboard. It may of course be used in local scenarios, too.

- *Mediation*, where the tables are arranged in several rows like in a traditional classroom. This configuration is kept in order to suit conventional, rather ex-cathedra styles of instruction.
- In addition, there is *Presentation*, a setup where all tables are moved to the niches of the CCF and replaced by comfortable armchairs. This configuration is not intended for teaching, but for cinema-like uses of the CCF related to the museum charter of the Ars Electronica Center.

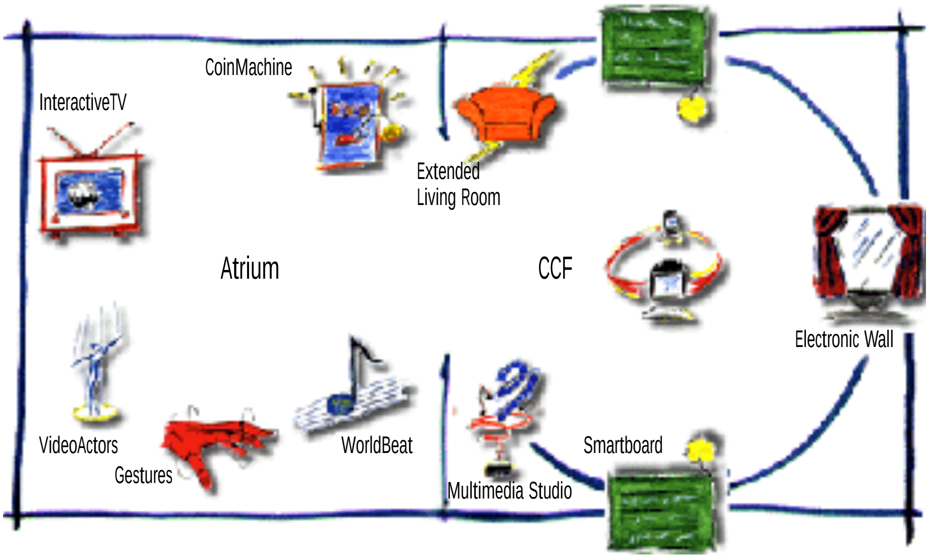

Figure 3: CCF floor plan

2.3 Cooperative Peripherals

Electronic classrooms are often designed under the implicit assumption that networked PCs become the center of focus for the learners. Thus either each learner uses a PC or they share one in pairs, and the teacher uses one, too. From our experience with creative cooperative meetings, we are convinced that this assumption is the *most fundamental error of today's electronic classroom designs.* Individual PCs are not wrong but insufficient. Rather, we believe that the traditional "center-of-focus" devices, such as blackboards, overhead projectors etc., have to be replaced by electronic equivalents. By center-of-focus we mean „everything that should draw the common attention of all learners“, may it be a presentation, the keyword list during brainstorming, notes about the current status of a creative meeting, the slides of an expert joining in, a video pan of a peer remote class, a combination of these, or whatever. Considering both today's technology and the changes expected with electronic classrooms, not all requirements can be matched yet by a single device. The next three sections provide further details.

2.3.1 The need for interactive electronic whiteboards

A vital and stimulating "social protocol" can be observed in front of a traditional whiteboard when small teams develop a concept during a creative meeting; in order to conserve this important social protocol, computers or tables must not be introduced as barriers; instead, interactive, pen-based electronic whiteboards must be used. They have to merge the paradigms of drawing board and pen/touch sensitive computer screen. Most important, remote peer classes (maybe equipped with their own electronic whiteboard) and local and remote PC users can share the virtual whiteboard software that runs on the CCF-based boards.

Several suitable products are on the market, maybe the most well-known one being the Liveboard™ [Elrod et al. 92]. Liveboards come as fully equipped PCs connected to an LCD projector, rear-projecting onto a pen-sensitive surface. Different pens yields different colors when moved over the projection surface or act as mouse-like pens. The whole is designed as a ready-made furniture. For the CCF, we preferred a competing product called Smartboard™ (//www.smarttech.com). Smartboards exist in several sizes and can either be purchased as entire systems or assembled from Smartboard-specific parts (pen/tray, sensitive whiteboard surface, connection kit and software, plus optional mirror and stand) plus separately purchased PC, projector and furniture. We wanted to configure and negotiate PC and projector separately and integrate the boards with our holistic CCF furniture design. In addition, the advantages of the Smartboard solution (such as finger sensitivity, Smart Ideas™ software for creative techniques, good integration with Intel ProShare™, optional coupling with MacIntosh™ computers and UNIX™ workstations) were given higher weights than the advantages of the Liveboard™ solution (such as writing without touching, recognition of boardmarker “colors” even if more than one marker is taken out of the tray, well-integrated handwriting recognition support).

2.3.2 The need for multiple center-of-focus devices

For conventional ex-cathedra instruction, the use of a single set of wall-mounted blackboards is appropriate since the teacher is conveying the information between blackboard and learners. However, more democratic or coached configurations like round-tables introduce what we call the *gooseneck-syndrome:* some of the learners always sit with their back facing the whiteboard; on the other hand, it is just these learners who have the shortest, obstacle-free access to the whiteboard, another kind of asymmetry. With electronic classrooms, this disadvantage of democratic setups can be compensated for if two synchronized electronic whiteboards are used. The CCF implements this concept and is going to evaluate it in more detail.

As we wanted to support center-of-focus devices even in the “teamwork” configuration described above, we ended up designing three such devices at different walls, one of them serving yet another purpose as discussed right below.

2.3.3 Advantage and feasibility of large electronic walls.

In contrast to blackboards, today’s interactive electronic whiteboards cannot be easily raised and lowered, nor stacked on top of one another as sliding “slices”. In addition, even state-of-the-art pen sensing with a resolution of about 3000 by 2000 dots does not yet yield the density and granularity of boardmarker strokes that would equal the non-electronic peers. As a consequence, an electronic whiteboard cannot present as much information at a time as a traditional set of blackboards. In part, the computer-based nature of the device compensates for this drawback since learners can copy and keep older contents and since scrollable regions on the board can simulate endless drawing space. Nevertheless, the at-a-glance display of larger amounts of information is a requirement which we consider important, even more so since the computer heart of electronic center-of-focus devices gives them the potential to display a variety of media and representations at the same time (think of the handwriting used to develop a formula, complemented by computer output of the corresponding algebraic curve and by natural phenomena which yield corresponding geometric forms).

Surveying the current state of technology, we found a reasonable solution to this problem: the Overview-mX™ family of stackable back-projection modules (//www.seufert.de; North America: //www.sv-systems.com). These devices can be stacked almost seamless, yielding a single computer display where the resolution scales up with the number of modules. A single module has a resolution of either 640 by 480 or 1024 by 768 pixels. The stability and sharpness of the picture are excellent since the framebuffer of the computer is directly used to address the transistors on the projected LCD display, i.e. the LCD pixels. (Note that usually, the framebuffer is translated into an analog RGB signal for computer monitors, translated back into digitial information inside the LCD logic.) We found that avoiding this "signal detour", the lower resolution Overview-mX module yields an appearance that can otherwise be found with high resolution LCD projectors only. In particular, we found Overview-mX to be superior to all known RGB beamer solutions for a number of reasons: i) the resolution scales up with the electronic wall size; ii) module depth remains constant of course, making back projection feasible for large size walls; iii) all-digital LCD addressing yields a stable picture so that no disturbing flickering effects have to be suffered when sitting or working directly in front of the wall (not to speak of radiation); iv) the picture can be clearly seen even from extremely sloping view-angles. The last two advantages are extremely important since we want to be able to move the desks almost adjoint to the electronic wall in the "telepresence" configuration (see 2.2) when we project remote peer classes on the wall.

The Overview-mX system comes with a custom VLSI designed controller acting as an X window server connected to the Ethernet. Since most of the CCF is based on Windows NT™, we had to find a solution for mapping MS Windows onto X window™. While Xserver software for Windows is available from a variety of vendors, there are only few products working the other way round. We found NTrigue™ to be a viable solution for this purpose.

As to the overall economic feasibility, electronic walls are still fairly expensive (the CCF design was restricted to a four-module solution for budgetary reasons), while the prices for interactive electronic whiteboards are declining considerably. Today, cost-effective solutions are available for about the price of four PCs.

2.4 Networked Workplaces

2.4.1 Operating System Trade-Offs

There was an endless discussion about which of the three major operating system alternatives to use, UNIX™, MacOS™ or an MS Windows™ flavor. In the end, our multiple roles – as a hub for austrian schools, as a peer in European and international electronic classroom projects, and as a testbed from which to draw for mass deployment of solutions tried out in the CCF – made us decide in favor of an MS Windows flavor. We have to stress that no conclusions whatsoever should be drawn from this decision regarding functionality and ease-of-use relative to the other choices. Many of our software tools will run under different flavors of MS Windows (W3.11, W95, NT) and in fact, most of our CCF workplaces are ready to boot different operating systems, even Linux (with more considerable restrictions as to the software tool compatibility). The mainstream offering, however, is Windows NT. Its stability and, in particular, superior multitasking and security features match well with our management/operation tools (see 4.1) which, e.g., need to control other operating system processes remotely. The decision in favor of NT also lead to two major drawbacks: i) compared to the other flavors, NT is known to be resource-devouring; ii) since we strive to use leading-edge technology, we find that due to market considerations, third-party vendors would usually offer NT drivers for interface cards and peripherals way after the release of drivers for other flavors.

We are using NT on our workplace and alcove PCs. In addition we use a DEC Alpha under UNIX for interfacing to the UNIX world, as a local file and video server, for managing the X server for the electronic wall, and for special compute-intensive tasks. Two more PCs are needed for the Smartboards, and we dedicated another PC to the electronic wall (running NTrigue and acting as an NT and CD-ROM server).

2.4.2 Issues of Portability and Monitors

We are currently using Pentium™ PCs with three multimedia peripherals (sound card, framegrabber card for analog video I/O, and MPEG-based decompression board), high-speed networking (see below) and, of course, graphics card and disk controller. The detailed decisions about the core PC hardware will not be discussed here in detail, lacking durable value to the readers. Only two key arguments are to be shared here: the deskside / laptop issue and the monitor issue. The price gap between desktop/deskside PCs and laptops is going to last for the foreseeable future. As a result, any given budget will yield more power and functionality using non portable hardware. We followed this rationale and use only a few laptops for the extended living-room and field excursions and for pen-controlling the electronic wall. We use desk*side* PCs in order not to occupy any of the restricted desktop space of our movable desks. Further advantages over laptops include higher modularity (in the light of rapidly evolving multimedia peripherals) and sufficient number of expansion slots.

As to the monitors, we argue much in favor of LCD monitors despite their cost. Standard CRT monitors render an electronic classroom much too technology-laden. Even worse, there is a placement dilemma. If CRTs are placed on the desk in the center of focus, they considerably hinder non-mediated conversation between local users, violating one of the most crucial design rules “get the technology out of the way”. If they are lowered considerably, a whole set of minor problems comes up like inappropriate viewing angles, glaring interference with workplace lighting, static and overall design problems with movable desks, etc. We did not find a satisfying solution here and advocate the upcoming generation of 14" LCD monitors. They can be easily moved on the desk according to the preferences of differently aged and sized learners, they are very much lower than 17" CRT monitors plus pedestals (to which they compare with respect to viewing comfort), and they can even be easily inclined for longer-lasting non mediated discussions.

Resuming from above, one might argue that standard PCs plus 14" LCD monitors sum up to the price of a laptop. However, we found that laptops with at least 12" LCDs and sufficient deskside expansion slots were extremely expensive, and did not even find a viable solution for the expansion cards we needed.

2.4.3 The Need for Two Different Networking Concepts

ATM-to-the-desk. Whereas the CCF will surely have to follow the rapidly evolving PC technology and replace many deskside components in the future, we tried to install a more long-lasting network solution. After a short interim period with switched 100 Mbit/sec Ethernet (100BaseTX, more precisely), we are about to switch to ATM OC-3 i.e. 155 Mbit/sec (Fast Ethernet will be used elsewhere in the center). The CCF is directly connected to metropolitan, federal and European ATM. We count on ATM-to-the-desktop despite the fact that for quite some time to come, classical IP and standard Internet protocols will be run on top of the ATM layers. During this period, we will not even fully exploit the available bandwidth since it will hardly be sustained by deskside hardware and applications. Even worse, today's ATM layers do not exploit many of the features that ATM was invented for (so-called permanent virtual circuits – still the only viable solution in many public ATM offerings – do not exploit the asynchrony and statistical multiplexing characteristics of ATM). However, we hope to be prepared for two more phases to come: an interim phase where dedicated ATM-aware applications exploit the bandwidth (for video conferencing, in particular), and the phase of maturity of ATM where both the ATM layers and the layers above make full use of the ATM potential. We are convinced that by then, ATM-to-the-desk will rule out each alternative. Using Internet / ATM today, we can freely interconnect the desktop video camera and audio (which is headset-based in order to avoid acoustic "pollution" in the classroom) among one another and with external classrooms and remote participants.

ISDN-to-the-classroom: Networking for electronic classrooms suffers from a problem that is not technology-bound: the telecom tariff structure in western economies. Since truly affordable high-speed tariffs would ruin the (low-speed, but technically related) telephone business, cashcow of every telecom, this dilemma is going to last for quite some time, despite increasing deregulation and competition especially in Europe. This means that ATM and any other high-bandwidth solutions will remain restricted to local and regional networks and to special use cases. To account for this situation, we installed an ISDN-based solution, too, linked to what we call *room audio* and *room video.* We believe that the limited bandwidth and inherently point-to-point nature of ISDN propose to link the entire electronic classroom to the outside world rather than individual desktops. The room audio installation uses a portable light-weight microphone plus a movable microphone on a tripod. The latter can be remote controlled, e.g., by the carrier of the portable microphone. All room audio input can be sensed and fed into the network independently by the three PCs adjoint to our cooperative peripherals. Any one of these can be assigned as ISDN hub. This PC feeds back audio from the network into the room speaker system (coming from peer classrooms and/or remote learners or experts). Room video works similarly. There is one camera mounted above the electronic wall for which zoom and swivel can be controlled by our dedicated classroom operation/management software. An automatic tracking function can be used in order to follow a presenter moving around in the classroom. The cameras located beneath the Smartboards can only be hand-adjusted at present.

Of course there is the question of why we do not feed the audio/video of individual desks into ISDN. We would indeed like to implement the so-called video-follows-audio function present in typical ISDN MCUs (multipoint control units, a term defined in the context of the standard for ISDN-based videoconferencing, T.120: typically owned by the network provider, MCUs connect to all conference participants, receive a video stream from each of them, but transmit back to all participants only one or few

– identical – video streams; many MCUs are capable of transmitting always the video stream of the current speaker). The reason why we implemented only the room audio/video solution instead is as follows: ISDN-based videoconferencing delivers decent quality only if the on-board H.261 compression support of ISDN videoconferencing solutions is used. For the time being, we have not found an easy solution for transmitting H.261 hardware-compressed video from an arbitrary (changing) desk to the ISDN public network. All viable solutions are very cost-intensive (one might equip each PC with an ISDN card and set up an expensive local MCU; or one might use additional analog wiring to connect each desk to a single ISDN hub and use computer-controlled analog mixing / multiplexing equipment).

3. Consumables for Electronic Classrooms

Computer-Aided learning (CAL) requires software tools just like traditional teaching requires tools and means. But ready-made and well-designed school books are not the only means used in the educational practice: much of a teacher's uniqueness and distinction and much of what makes lessons interesting come from the individual touch of teaching styles and teaching material. Multimedia based CAL buries a high risk of reducing this individual touch since the development of instructional material becomes extremely cost and labor intensive and requires expertise in different fields (multimedia CDs are usually developed by teams of experts). This problem is aggravated by the expectations associated with the keyword multimedia, raised by million-dollar developments from the film and entertainment industry, hard to double by a single teacher. Due to these considerations, teachers are inclined to using nothing but highly sophisticated, purchased instructional material, e.g., based on multimedia CD-ROMs.

In conventional schools, individual teaching styles and material are based on "consumables" such as chalk, photocopies, and transparencies, and on a wide variety of commodities and consumables for setting up experiments in natural science disciplines.

We believe that current CAL research pays too little attention to the computing equivalents of such consumables. In order to make individual development of instructional material feasible for teachers, they must be able to draw from highly customizable, but easy to assemble components, and from templates that come with sophisticated editors for customization. Due to the early state of the art, the following sections can only describe *some* of the consumables needed for electronic classrooms. (Of course, "consumable" is only a metaphor here since software is an unlimited resource.)

3.1 Videoactors

In order to render multimedia documents attractive and instructive, animated characters are often used. One field of application is context-sensitive help, found in an increasing number of commercial software products. There, the characters walk over the screen, point at a given part of a computer window (e.g., a button, menu, etc.), and explain its signification using digitized voice output or text in balloons. Animated characters like this may be used for many other purposes, such as on-line handbooks and on-line learning material, multimedia presentations etc.

However, drawing such animated characters and making them behave as required in a given context requires expert designers and multimedia programmers, and usually considerable time and budget. VideoActors reduce this task to a couple of mouse clicks in a tool called VideoActors Editor. If a user (teacher) wants to augment a multimedia presentation or software with VideoActors, he has to perform the following steps in this editor: i) select the desired character from a set of prebuilt ones; ii) identify the first atomic action that this character shall carry out, selecting again from a set of prebuilt one such as 'walk', 'point', 'talk'; iii) provide parameters for the action, such as the trajectory to walk along (via mouse clicks); iv) repeat the preceding two steps for subsequent atomic actions until all elements of a coherent animation are provided. At the end, the system automatically compiles a Videoactor, i.e. cartoon film as specified (in fact, VideoActors are a special kind of Quicktime™ movie). The result has to be linked to the desired part of the multimedia presentation or software.

This functionality requires building blocks (set of walking steps, set of arm movements and many more) to be prebuilt such that concatenating and superimposing them yields smooth operation of the VideoActors. Digital blueboxing is used in order to superimpose the underlying screen windows with the moving VideoActors. Blueboxing means that the building blocks of the VideoActors are drawn on a blue background which indicates to the superimposition software which parts of the video rectangle on the screen become transparent and let the actual computer screen "shine through". Figure 4 shows two VideoActors, of course only as a snapshot of an actual animation (the character chosen symbolizes the Upper Austrian special dish "Knödel").

VideoActors are a sample set of consumables, showing how the individual development of attractive and sophisticated multimedia may become affordable. Of course, this advantage comes at the price of restricted choices, but there is still ample room for individual customization.

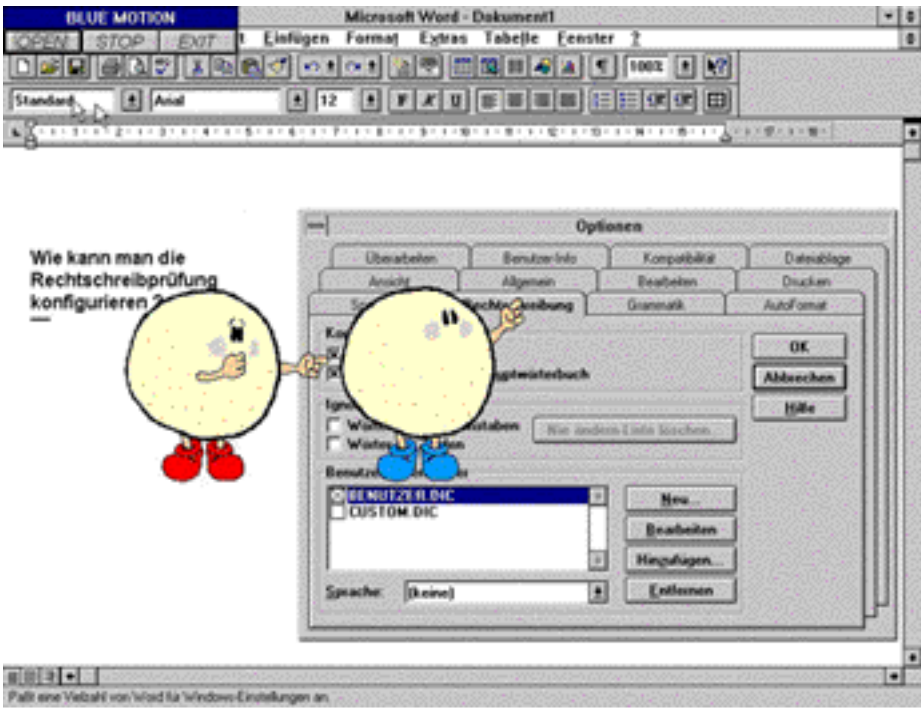

Figure 4: VideoActor snapshot (sample use of "consumables")

3.2 Instructional Objects

A library of customizable object classes for the development of instructional material is under way, drawing from work carried out in the afore-mentioned predecessor project Nestor and in a European project called Demos in which the CCF participates. Since this development is still ongoing and will last for some time to come, we will only briefly describe the four categories of instructional objects:

- *Learning-World objects:* we are developing building-blocks for a *virtual learning environment,* based on a virtual world where learners can participate in forums and discussions, access information sources, and insert actors as their own substitutes.
- *Cooperation objects:* drawing from the projects mentioned, an object library and method are built which support the creation of cooperative instructional material. The rationale is twofold: i) Serious cooperation among and with learners can hardly be realized using only off-the-shelf cooperation tools that are unaware of the course of learning, task assignments, etc.; thus, cooperation must be customized and *built into* teaching material. ii) Building cooperation-aware material is tedious; thus, cooperation objects and development methods are needed to simplify matters.
- *Instructional transaction (IT) objects:* interactive instructional material is composed of small steps that are often called IT. For a canonical set of such IT types, we want to offer a library of IT objects in the CCF. Most CAL authoring tools on the market offer a set of IT types plus means for assembling them in a "flow-chart" like manner into a course of instruction. We want to decouple the IT types (as an object library) from the process that drives the course of instruction. For the latter, we propose an approach which i) combines rule-based and procedural aspects; ii) covers an explicit design phase preceding the "implementation" steps; and iii) enforces an overall instructional strategy. This approach, called WebStyle, is described in 3.3.
- *Multimodal objects:* for this library under construction, we leverage off an object-oriented approach to the development of multimodal user interfaces [Gellersen 95]. Based on this approach, teachers can develop instructional material which can interfere with different modalities. The term modality denotes a "way of interaction", such as by using handwriting-based metaphors or by combining several I/O channels (a famous example is the combination of speech and mouse input for "put-that-there": command names are spoken, operators are pointed out).

As to the last category mentioned, a preconfigured example of a novel modality is shown in the CCF atrium, in an exhibit called Gestures: this exhibit uses natural human-computer interaction, based on hand gestures. The user's hand is input using a simple desktop camera, like the ones used at the CCF desks. Hand contour and position, and the type of hand gesture are detected using sophisticated recognition techniques. For the fundamental algorithms used, see [Broeckl-Fox 95]. Visitors drive a simple arc-and-bow game for illustration purposes. In the context of the multimodal object library, gesture-based interaction will become one of the choices. Such objects may, for instance, be integrated in presentation management software for the electronic wall.

3.3 WebStyles

When subject matter experts consider the use of an electronic classroom, they often realize that they are not sufficiently familiar with the discipline of instructional design

[Gagné et al. 92], let alone with rapid advancements in this discipline. Such advancements are related to the use of computers and focus on autonomy [Dickinson 95], to an emphasis on cooperation [Mühlhäuser, Rüdebusch 94], and to the use of new means like WWW [Ibrahim, Franklin 95].

The WebStyle approach tries to compensate for this problem by offering prebuilt instructional strategies in the form of so-called hypermedia document types. Since the idea of a hypermedia document *type* is not yet very popular, we will briefly sketch it here. The initial idea is that characteristics of a whole set (or family) of Hypertext documents can be commonly described in a type. In the CAL context, such a type may correspond to a particular instructional strategy. Among other things, the type defines which kinds of hypertext elements (nodes and links) make up a strategy-compliant hypertext document and how they may and may not be assembled. Using the WebStyle approach, these properties are defined by specifying mandatory, optional, alternative, and repetitive elements (and configurations) of a type-compliant hypertext document.

The use of a WebStyle leads to a common look and feel of the set of documents derived from a common type. Much more important, it allows sophisticated navigation and guidance as well as sophisticated user models to be programmed *in a reusable way* as part of the WebStyle, based on a combination of rule-based and procedural approaches. All this can be inherited when a hypermedia document instance is derived from a type.

In terms of consumables, the following scenario describes the simplification and reusability gained for an author (teacher): trying to edit comprehensive instructional material, she selects the particular WebStyle that represents the most suitable instructional strategy (explorative, game-based, directed, cooperative and other categories may exist). A WebStyle editor guides her during the task of mapping contents and media onto a WebStyle-compliant hypermedia document. Thereby, the rules and procedures for navigation support and user modeling are (for the most part) automatically inserted into the document, as defined in the WebStyle. Note that the notion of hypertext navigation as used here is much more sophisticated than what explorative WWW browsers usually offer; on the other hand, the WebStyle approach is a WWW-compliant extension to the so-called PreScript concept developed in the context of project Nestor. For a more detailed discussion we refer to [Richartz, Mühlhäuser 93].

4. Tools and Curricula

4.1 Educational Toolsets

The possible tools for an electronic classroom form and endless list. The whole literature about instructional, CSCW, management, authoring, multimedia and other tools might be cited here. Since this layer of our logical architecture is subject to world-wide discussions and research and development, we do not need to stress it here. We just want to draw the reader's attention at the following categories of tools which we included in our initial CCF setup – and to the fact that for some of them, an astonishingly low number of corresponding off-the-shelf solutions exists, so that tools had to be developed by ourselves.

- *Elicitation and authoring tools:* Hypermedia / multimedia browsing and authoring tools represent a key category here for which off-the-shelf solutions are widely available. Among others, the Netscape™ browser, Macromedia Director™, and single-media editors like Adobe Photoshop™ figure on our shopping list here today, but the fast moving market may suggest other decisions tomorrow. An example of an elicitation tool that is *not* readily available in other electronic classrooms is demonstrated in our InteractiveTV exhibit. The exhibit is intended to show a pathway from upcoming digital TV to more advanced interactive TV solutions.

As part of this exhibit, we developed a TV news database based on the daily news feature of the austrian broadcasting company, ORF. Along with the news, teletext-based subtitles are broadcast, intended for hearing impaired. These subtitles are retrieved with a PC teletext decoder and stored as a computer-readable, text-based index to the individual news clips (digitized and stored on disk, too). This news database with text-based front-end can be automatically updated on a daily basis. CCF trial uses have already shown the importance of elicitation tools like this one and like the Internet personal news tool PCN (//www.pointcast.com).

- *Cooperation and operation tools:* Myriads of cooperation and videoconferencing aids are on the market, but many issues of quality, interoperability, and sophisticated LAN-WAN-LAN multicast (cf. [Boyer 96]) are still open. In order to suit different scenarios of use, we have to rely on different solutions like the mbone tool suite [Macedonia et al. 94] for multicast conferencing, CU-SeeMe [Dorcey 95] for star-configured Internet conferencing, and Intel ProShare™ for ISDN.

  These videoconferencing tools are complemented by facilities for so-called application sharing (multiplexing the I/O of arbitrary software onto multiple desks) and for joint editing. By the time this article is written, several tools for these two purposes are in use, no final choice has been made; interested readers should contact the author for more information.

  The above is complemented by two tools developed by ourselves. One of them is PinUp, an enhanced electronic whiteboard software capable of *recording* the evolution of whiteboard sketches over time. Using this tool, the evolution of a sketch (a cooperative design, for instance) becomes revisable like a video. PinUp allows the introduction of scrollable regions, even nested ones, everywhere on the board. In contrast to most existing whiteboard tools, it supports object-oriented (instead of raster) graphics and thus offers more sophisticated manipulation of sketches. Written in Java™, it can be well integrated with other Netscape™-based assets.

  The second home-grown tool fights the most important nuisance identified in the tool layer: today, a teacher must have *system manager skills* in order to control the cooperative use of tools (such as application-sharing, whiteboard, or videoconferencing facilities). To compensate for this lack, an easy-to-use group management system GMS is developed with a graphics/picture based interface. GMS supports desk identification via topological position (of course only for desks local to the CCF, supporting all configurations discussed in 2.2), user photograph, or easy-to-remember graphical desk icon (instead of Internet address). Using a point-and-click interface, authorized users can assign and manage groups and relate tools to individuals or groups for videoconferencing, joint editing, task assignment, and so on.

- *Instructional design tools:* In order for teachers, authors, or presenters to *plan* multimedia courseware or presentations, tools like storyboard design aids, time planners, instructional design editors, and feedback evaluation tools are needed. Today, a teacher must usually rely on general-purpose solutions like software development tools and project planning tools. For the CCF, instructional design specific planning tools are under development, based on the WebStyle concept mentioned in 3.3.

4.2 Curricula

Early on in the project, we included content development and curricula planning in our integrated approach. It was indeed crucial to elicit user requirements in a dialogue between the CCF project team, authors, and end users (teachers, learners), and to have teaching material available in time. However, we found that despite the technical expertise found among teachers, a deep understanding of the new possibilities offered by advanced electronic classrooms did not exist and could not be sufficiently conveyed via “theoretical” instruction.

In order to fight this problem, the researchers from the telecooperation group had to develop “tangible examples”. More precisely, two sample contents – in the form of exhibits for CCF alcoves – and a feature video were developed which illustrate a subset of how electronic classrooms can be used:

- The CoinMachine alcove shows a LegoLogo installation including a train, a conveying system, and other parts. It represents a (high-level, visual) programming task. The program to be quickly assembled by the user drives the installation up to either successful termination (a coin is released) or program error; in the latter case, the reason is discussed and a new trial is offered. We advocate the possibility to develop computer-controlled models since they provide tangible computing experience [Yelland 93]. The CCF can be equipped with up to twelve sets of LegoLogo building blocks, connected to the CCF PCs, where similar projects can be carried out.
- The WorldBeat computer music installation shows that, using two Bucla Lightning virtual batons (//www.buchla.com), even unexperienced users can quickly produce aesthetic music (by playing instruments or directing an orchestra). In one of the WorldBeat modules for instance, the basic parameters of a blues scheme, like groove, tempo, and bass movement can be set, a solo instrument can be picked, and then the blues harmonic scheme is used for accompanying the solo instrument played by the learner. The learner uses the batons as if she would strike an invisible vibraphone. The novelty lies in the fact that at any given time, the computer offers only those notes on the vibraphone which fit with the accompanying background. On one hand, this “you can’t play wrong” kind of module offers a new, instantaneous way of performing music with the computer and peer players. On the other hand, it leads to the pedagogically interesting topic of what makes up aesthetic music. A whole world of music-related issues and topics is accessed through this easy-to-use door, all in one providing an extensive curricular cycle about music.
- While CoinMachine and WorldBeat demonstrate the importance of tangible and audible feedback and of quick and easy access to a deep subject, many other visions discussed in this paper and rendered possible in the CCF cannot be conveyed by an exhibit. Therefore, a feature video was assembled. It shows how a test class treated the subject “our solar system” and used many of the afore-mentioned tools and consumables in a coordinated way. Emphasis was put on the interdisciplinary effects (during the class, issues were raised that pertain to history, biology, math, and physics); the example also illustrates very well how cooperation, knowledge elicitation, and even teaching skills are acquired as a “side effect”.

In conclusion, we can summarize our experience about curricular use as follows:

- Early involvement of users provides valuable input to system requirements.

- Early inclusion of content development yields an electronic classroom which is not only usable in principle, but actually used. In our case, “project packages” were developed for the initial contents developed. It comprises on-line and paper-based material to be used in preparation of the CCF use, during its use, and afterwards. Apart from few examples (see below), the first “wave” of contents cannot be expected to fully exploit the possibilities of an electronic classroom.
- User involvement does not replace the need of a clear, far-reaching vision of the developers of electronic classrooms, and “theoretical” information about advanced uses of electronic classrooms cannot replace sample demonstrations.

By the time this article is written, the CCF has just opened to the public, so that no experience about working with remote peer classrooms exists. This should change in the context of the Demos project and of an Internet-wide music-related activity started.

5. Conclusion

An unexpected conclusion must be drawn from this report about the CCF classroom of the future: the most important change required does not concern hardware or software, but the roles of the humans using it. If these new roles are assumed, future electronic classrooms become hubs for cooperative knowledge elicitation.

In the envisioned setup, classrooms have a lot in common with meeting rooms. Learners team up – locally and remotely – in order to find, process, and convey information. Subject matters become interdisciplinary; cooperation and knowledge elicitation skills are a key concern, acquired as a side-effect while other subject matters are treated. Teachers become more similar to coaches and cannot draw learners’ respect from an information advantage any more.

A four-layer architecture was proposed to accommodate these changes. Some of the key issues in these layers can be summarized as follows:

- For the *facilities* layer, we emphasize center-of-focus devices which replace conventional blackboards. A flexible desk configuration, LCD screens, and a network that supports both information access and telecooperation are suggested. “Minor” issues like tariffs or cabling become key concerns.
- The *consumables* layer is largely under-estimated in the state of the art, but strongly required if the creative role of teachers is to be maintained. Multimedia development aids like VideoActors, a variety of instructional objects, and re-usable instructional strategies (in the form of WebStyles) are proposed as important composites of this layer.
- While the *toolsets* layer has received a lot of attention in international R&D, some important tools are still missing, like easy-to-use operating aids for electronic classrooms; others, like videoconferencing tools, are not yet sufficiently mature.
- For the *curricula* layer, early user participation was considered crucial. However, it turned out to be difficult to convey the vision of future electronic classrooms to the users before the room as such was available. Therefore, sample contents were developed. They emphasize the above-mentioned new roles of teachers and learners, as well as “tangible and audible” feedback in the form of easy and successful early contact with the subject matter (cf. WorldBeat and CoinMachine).

6. References

[Boyer 96] Boyer, D.G., and Lukacs, M.E.: "The Personal Presence System: a Wide-Area Network Resource for the Real-Time Composition of Multipoint Multimedia Communications"; Multimedia Systems 4, 3 (1996), 122-130.

[Broeckl-Fox 95] Broeckl-Fox, U.: "Real-Time 3-D Interaction with up to 16 Degrees of Freedom from Monocular Video Image Flows"; Proc. Intl. WS Automatic Face- andGesture-Recognition, Springer Heidelberg (1995).

[Dickinson 95] Dickinson, L.: "Autonomy and Motivation – a Literature Review"; System 23, 2 (1995), 165-174.

[Dorcey 95] Dorcey, T.: "CU-SeeMe Desktop VideoConferencing SW"; Connexions 9, 3 (1995)

[Elrod et al. 92] Elrod, S., et al.: "Liveboard: A Large Interactive Display Supporting Group Meetings, Presentations And Remote Collaboration"; Proc. ACM CHI'92 Conference on Human Factors in Computing Systems, Desks, Video, and Screens (1992) pp. 599-607.

[Gagné et al. 92] Gagné, R., Briggs, L., Walter, W.: "Principles of Instructional Design"; Harcourt, Brace, Jovanovich, New York, 4th ed. (1992).

[Gellersen 95] Gellersen, H.-W.: "Toward Engineering for Multimodal Interactive Systems"; Proc. 1st WS Intelligence & Multimodality in Multimedia Interfaces, Edinburgh (1995).

[Ibrahim, Franklin 95] Ibrahim, B, Franklin, S.D.: "Advanced Educational Uses of the World-Wide Web"; Computer Networks & ISDN Systems 27 (1995), 871-877.

[Macedonia, Brutzman 94] Macedonia, M.R., Brutzman, D.P.: "MBone Provides Audio and Video Across the Internet"; Computer 27, 4 (1994).

[Mühlhäuser 95] Mühlhäuser, M.: "Cooperative Computer-Aided Authoring and Learning", Kluwer Academic Publishers, Doortrecht (1995).

[Mühlhäuser, Rüdebusch 94] Mühlhäuser, M., Rüdebusch, T.: "Cooperation Support in Computer-Aided Authoring and Learning"; in: Ottman, T., Tomek, I. (Eds.): Educational Multimedia and Hypermedia Annual (1994), AACE Charlottesville VA, 397-402.

[Richartz, Mühlhäuser 93] Richartz, M., Mühlhäuser, M.: "PreScripts: A Typing Approach to the Construction and Traversal of Hypertext" in: Maurer, H.(Ed.): Educational Multimedia and Hypermedia Annual (1993) AACE Charlottesville VA, pp. 436 - 443.

[Yelland 93] Yelland, N.: "Young Children Learning with Logo: An Analysis of Strategies and Interactions". Jrnl. Educational Computing Research 9, 4 (1993), 465-486.