Chapter 3

The E-Chalk System

In 2000, upon initiation by Raúl Rojas, the *E-Chalk* project [73] started with the idea of "creating an update of the traditional chalkboard" [Rojas et al., 2001a, Rojas et al., 2001b]. Since then, the system has evolved in response to feedback from its users. In the computer science department at Freie Universität Berlin alone, about 300 lecture recordings[1] have been created since 2001. The following sections summarize both the ideas that motivated the creation of E-Chalk. and the thoughts that evolved in response to the user feedback.

3.1 E-Chalk's Philosophy

Main Target: Classroom Teaching

A teacher's main priority is classroom teaching, not least because that is what he or she is paid for today. Teachers will not accept a tool with which their experience and practical knowledge, gained through a lifetime of teaching, cannot be reused. An excellent teacher should remain an excellent teacher no matter whether he or she makes use of electronic aids or not. There should be as little overhead involved as possible in familiarizing themselves with a given technology. Hence, any tool has to ensure that it conforms to the teacher's established working habits while offering added value. Since every teacher has different ideas about what a good lecture looks like, teachers need to be able to customize the tools according to their preferences and ideas.

Support both: Prepared and ad-hoc Lectures

A smooth lecture performance directly depends on the quality of the preparation. Preparation consists of gathering content, structuring the lecture, and preparing of other material, such as charts, figures, or pictures. There is no doubt that multimedia elements are very useful teaching tools. Consequently, the increasing use of such elements leads to an even higher preparation effort. In order to avoid redundant work (e. g., pre-sketching the lecture on paper), computer-based education tools must support this process in a convenient way. Convenient here means preserving as much freedom as possible while allowing as

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[1]At the time of writing this document, I count 294 recorded courses (not including experimental recordings, show cases, and special events).
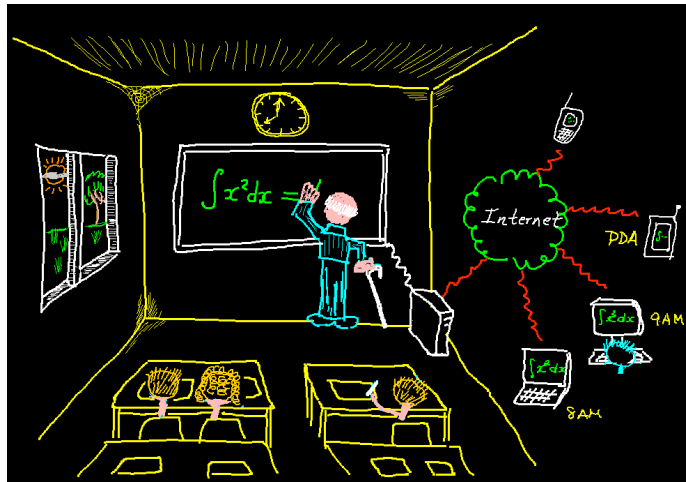
Figure 3.1: This sketch, drawn by Raúl Rojas, illustrates the general idea of the *E-Chalk system*. A bald-headed professor walking with a cane is able to work with the intelligent electronic chalkboard just as he used to with a traditional chalkboard. The lecture is archived and transmitted via the Internet and can be received on a variety of devices, including mobile phones and PDAs.

much structure as needed. A teacher should still be able to control the amount and order of elements that are to be included in the lecture. An experienced professor for example is able to hold an excellent lecture spontaneously backed by lifetime-experience only.

Support Distance Teaching as a By-product

Synchronous remote teaching, such as video conferencing, can allow for courses that, due to limited resources, would be otherwise impossible to implement. In addition to helping students recall past lecture content, asynchronous remote teaching provides benefits that assist students in reviewing past lectures in order to catch up on missed content or prepare for examinations, and, if they are physically handicapped, gives them greater overall access to lectures. Additionally, institutions promote lecture recording and broadcasting because they anticipate that these archives will enhance the institution's knowledge base and enhance its prestige. Synchronous and asynchronous teaching offers a valuable enhancement for students, but teachers will implement it only if doing so entails as little overhead as possible.

Focus on the Chalkboard, not on Slides

The main advantage of slides (for example discussed in [Holmes, 2004]) is their reusability, which is at the same time their biggest downside: Slide-show presentations often appear static because everything has to be planned in advance leaving little room for the teacher to adapt the content in interaction with the students. This often leads to the situation that information is either delivered out-of-band, i. e., not presented in the slides (for example, many lecturers prefer to draw their diagrams by hand, instead of spending hours of preparation in

advance) or students are overwhelmed by the huge amount of slides displayed in rapid succession. Usually, slides present content as bulleted point lists. This dramatically restricts the expressiveness of the lecturer. A famous, but also controversial [9], critique of PowerPoint was published by Edward Tufte [Tufte, 2003]. Among the most important points he raises: Slides are used more to guide and reassure the presenter, rather than to enlighten the audience; they encourage simplistic thinking, because ideas are forced into bulleted lists; the presenter and the audience are forced to linearly progress through the presentation, sometimes causing them to miss the big picture.

Slide-show presentations are used very frequently. However, in several subjects, especially in the sciences, it is often said that they do not meet the instructor's requirements. Especially in mathematics and physics, the journey is the reward and one is not interested in results presented on slides but on the development of thoughts that led to them. The chalkboard has been an established teaching tool for many decades. The lecturer thinks aloud while writing on the board. The students have enough time to understand an idea or formula, ask questions, and reflect on the contents of the lecture.

Integrated Concept

Figure 3.1 is a sketch drawn by Raúl Rojas that illustrates the overall concept of the E-Chalk system. In essence, the idea was to create a tool that substantially facilitates the preparation and holding of lectures, allows the integration of various media, and supports (a)synchronous remote teaching with little or no overhead for the lecturer. The most important policy is on the one hand to provide the highest amount of assistance while on the other hand permitting the greatest degree of freedom during class. The primary purpose of E-Chalk is to support the teacher in the classroom. Creating distance learning courses for the World Wide Web [Raffel, 2000] is only a secondary consideration. E-Chalk is actually a conceptual idea that integrates many components, involving hardware as well as software. However, for the rest of this text, the word "E-Chalk" or the words "E-Chalk system" denote the E-Chalk software system.

E-Chalk is representative of the idea of technically-augmented classroom teaching and, due to its additional distance-teaching features, also can be considered an implementation of blended learning.

3.2 The Software System

The next sections are mainly a summary of [Friedland et al., 2004e]. They provide an overview of the features of the E-Chalk software. The design of the chalkboard simulation and the integration of different interactive content on the electronic chalkboard is described in [Knipping, 2005]. An overview of the project and a list of contributers is presented in Appendix A.

E-Chalk transforms the computer screen into a black surface where one can paint using different colors and pen widths. The screen becomes a visual output tool that delivers content to more than one person. This requires that everything shown on the display can be watched and understood by many people. The keyboard loses its importance and needs to be used only occasionally. Any required use of the keyboard is to be avoided since it breaks the flow of the
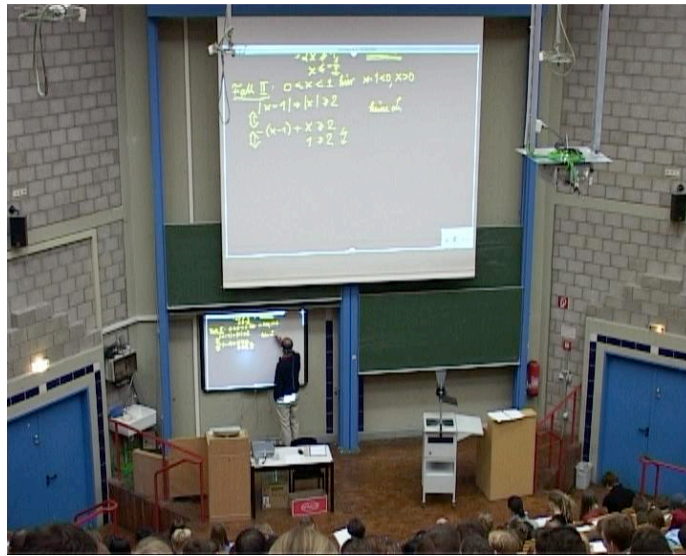
Figure 3.2: An E-Chalk setup for larger lecture halls: The instructor is writing on a pen sensitive whiteboard and a second projector is used to enlarge the content for the students.

lecture. Furthermore, the mouse is not an adequate input device in a classroom scenario because the lecturer is standing in front of an audience rather than sitting in front of a desktop. These considerations dominate the entire design of the chalkboard simulation software and any software that is to be run during the lecture.

The board can be scrolled up and down vertically, providing the lecturer with an unlimited surface to write on. The user can also use an eraser to delete parts or all of the board content. The board software allows the placement of diverse visual and interactive material on the board. The material may be imported from the Internet during a lecture but is usually chosen from a set of predefined bookmarks in order to avoid having to use the keyboard during a lecture. The elements that are most prominently used to enrich an E-Chalk-based lecture are diagrams and photographs. These may also be retrieved from the Internet during a lecture using an interface to *Google Image Search* [77]. Images inserted in the board can be directly annotated. Bookmarked sets of images may be used to present slides one after another on the electronic board. The advantage here is that the slides can be annotated which enables the combined use of slides and the chalkboard. The E-Chalk system also allows the insertion of certain[2] Applets. This allows the integration of educational mini-applications, as many of them are available as Applets. Access to CGI scripts [68] has been implemented as a way of interfacing web services. The board shows both textual and graphical responses. E-Chalk also provides an interface to the algebra systems Mathematica, Maple, and MuPAD. It also integrates a small self-made algebra system called *Rüssmans Minimatica*. The latter is able to solve simple arithmetic expressions and provides 2D and 3D function plots, including trigonometric functions. To enter mathematical problems to be solved by the

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[2]For a detailed discussion see [Knipping, 2005] Section 4.10.

Figure 3.3: A demonstration of the four screen interactive datawall construction at Freie Universität Berlin for middle-sized seminar rooms.

interfaced systems, the system provides an integrated mathematical handwriting recognition [Tapia, 2005, Friedland et al., 2004d].

Finally, the E-Chalk board system provides a unique interface for stroke-based applications, called *Chalklets*. These applications interact exclusively through strokes, i.e., they are able to recognize drawings and gestures from the screen and respond by drawing their results on the board. Several Chalklets have already been developed, among them a Chalklet that simulates logic circuits [Liwicki and Knipping, 2005], a chess interface [Block et al., 2004a], a Python programming environment, and a Chalklet that can be used to log geometry proofs.

In order to allow the advance preparation of chalkboard lectures, the board software supports so-called *macros*. Macros are pre-recorded series of events that a lecturer may call and replay on the board during a lecture. To record a macro, the instructor draws the portions of the lecture which he or she wants to store in advance. During the lecture, macros are replayed either at original speed or using an acceleration factor. Automatically generated macros can be used for visualization purposes [Argüero, 2004].

3.3 Usage Scenarios

The E-Chalk software works with a variety of hardware that instructors can use to substitute the traditional chalkboard. The ideal *electronic chalkboard* would be a large, pen-sensitive screen with high display and sensor resolution. The display must offer good contrast, so that the visual quality can be compared to a real chalkboard, e.g., it should not be required to darken the room for the lecture. However, an idea like E-Chalk depends on the instructor's and the students' preferences. [Friedland et al., 2003] studies different types of hardware setups that people have found useful.

To have many students in a lecture room requires a very big display surface. The practical solution is to use a digital whiteboard (for example from GTCO CalComp, Inc. [28], Hitachi, Inc. [24], Numonics Corporation [36], or

Figure 3.4: Sample setup where the E-Chalk system is combined with a conferencing system for bidirectional synchronous remote lecturing.

Smart Technologies, Inc. [49]) or a digitizer tablet (for example from Wacom Corporation [91]) as a writing surface plus an extra projector that projects the board content in large. The Technische Universität Berlin, for example, uses this setup regularly for mathematics lectures for undergraduate engineering students [Friedland et al., 2005f]. Figure 3.2 shows this setup.

Due to the non-availability of large pen-sensitive screens we built a low-cost, scalable, interactive datawall in a dedicated seminar room at Freie Universität Berlin [Friedland et al., 2005g]. Figure 3.3 shows a photograph of the setup. The datawall is operated by two off-the-shelf PCs, one PC to actually work on and a second one for the pen-tracking system. A multi-head graphics card controls four screens with a total projection area of $1.15\,\text{m} \times 6.13\,\text{m}$ and a resolution of 4096×1024 pixels. In order to keep the depth of the datawall compartment small and to avoid using expensive wide-angle projectors, the screen images are reflected by mirrors. The instructor uses a special stylus, a laser pointer with a touch-sensitive tip, to write on the board. When the pen touches the screen, the laser lights up. A vision system uses four regular web cams to capture a video image from the back of the datawall, in order to track the red laser spot. The laser pointer's position is mapped into the coordinates of the display system which runs a Java-based client program emulating a mouse device [Jantz et al., 2006].

For smaller seminars, a setup with several digitizer tablets is often used, where students are able to directly participate in the lecture. A geology lecturer, for example, often uses a rear projector and the students use small digitizer tablets to work on geographical maps. A handicapped professor for Arabic linguistics was glad to be able to give a chalkboard lecture while seated using a digitizer tablet for himself, instead of writing on the rear projection screen. This scenario is also useful for a German high school: The computer room of this school is so small that neither a chalkboard nor tables for the students big enough for a computer and writing space fit in. The teacher uses E-Chalk with a digitizer tablet and projects the board content onto the wall. The generated
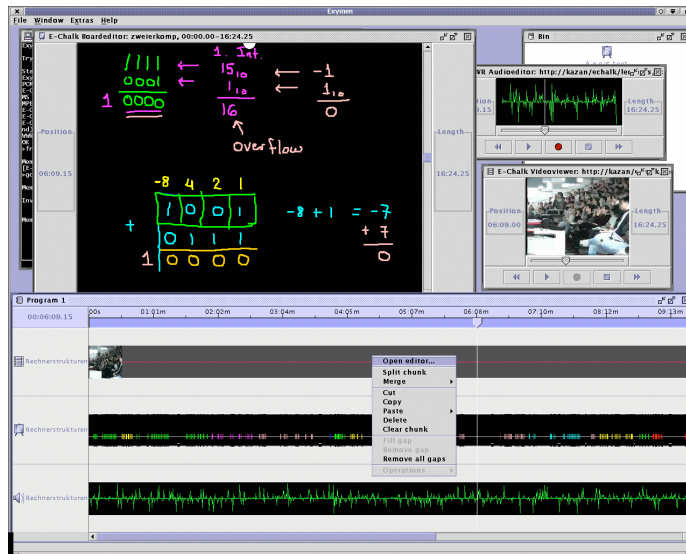
Figure 3.5: This screenshot shows Exymen [Friedland, 2002a] editing an archived E-Chalk lecture that contains audio, board content, and an additional video.

PDF of the lecture is printed out at the end of the class, so that the students can get a copy of the class even though they do not have enough space for writing.

Because everything is recorded for the web (see Section 3.4), it is also possible to give a lecture at home and present it later. Many high school teachers reported that they find this a practical feature because they can easily create classes for the students to review at home. This makes it possible to teach more content.

E-Chalk is also often used in combination with video conferencing systems, which enables having audiences in several remote locations at the same time. Following chalkboard lectures by important personalities that are held at a different place is an example application for this scenario. Figure 3.4 shows a cooperative lecture between FU Berlin and Kyoto University.

3.4 Distance Teaching

When an E-Chalk lecture is closed, a PDF transcript of the board content is generated automatically. The transcript can be generated both in color and in black and white. The lecture can also be transmitted live over the Internet and can be synchronized with video-conferencing systems (such as Polycom ViaVideo [40]) for student feedback. Remote users connect to the E-Chalk server to view everything as seen in the classroom. They can choose to receive the audio and optionally a small video of the teacher. The connection speed needed for a complete E-Chalk lecture with blackboard image, audio, and video is roughly 128 kbit/s. Without the video stream the required connection bandwidth does not exceed 64 kbit/s. The most convenient way for users to follow a lecture is to use the Java-based playback. In this case nothing but a Java-enabled web browser is required. When viewing archived lectures, the remote user sees a control console that enables controling the playback of the content the same as

with a VCR, i. e., pause, fast-forward, and rewind. There is no need to manually install any plug-in or client software. Other options include to follow the lecture in MPEG-2 format on a DVD, to use a Java-enabled PDA, a third-generation mobile phone using RealPlayer, or an Apple iPod capable of playing MPEG-4 videos. Chapter 5 provides a detailed discussion on E-Chalk lecture playback.

3.5   Editing Lectures

Although E-Chalk has been conceived as a tool for capturing live and spontaneous lectures, it is only natural that instructors would sometimes like to edit the recording of a lecture, in order to erase and correct errors, or just to eliminate superfluous material. For editing E-Chalk lectures, the program *Exymen (Extend Your Media Editor Now!)* was developed [Friedland, 2002a, Friedland, 2002b].

Exymen allows to edit audio, video, slide-show, and board content in any format that E-Chalk supports (see Section 4.9). Additionally, E-Chalk lectures may be enhanced with external material. The editor allows for spatial and timely cut, copy, and paste of pieces of lectures. It is able to separately handle audio, video, and board streams, for example for dubbing lectures for a different audience. The editor contains a set of audio and video filters that can be applied to a lecture. Exymen may also be used to convert E-Chalk lectures to different formats, such as MPEG video. Figure 3.5 shows a screenshot of the editor.