E-Chalk: a lecture recording system using the chalkboard metaphor

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This article describes a system that produces web based learning modules as a by-product of regular classroom teaching. The lecturer uses a pen sensitive display in place of the traditional chalkboard. In addition to drawings, the electronic chalkboard handles a range of multimedia elements from the Internet. The system records all actions and provides both a live transmission and a replay of the lecture from the web. Remote students follow the lecture looking at the dynamic board content and listening to the recorded voice of the instructor. Several use cases of the system as well as a systematic evaluation in two universities are presented.

Keywords Lecture recording system, board metaphor, evaluation, use case

1. INTRODUCTION

Using conventional authoring systems, the ratio of production time versus duration of the produced learning unit is typically a two to three digit number. Generally, this is not economically viable, especially as content of university lectures changes quickly. A cause for this tremendous effort is that traditional teaching know-how does not easily match contemporary authoring tools. Besides technical efforts, it requires huge amount of work to structure pedagogical content for the web. Trying to avoid these expenses, many universities use mere video capturing of their lectures. This approach does not only need technicians present during the recording to handle the camera and the audio hardware, but also standard Internet video web cast tools are inadequate for this kind of content. Writings and drawings, from slides or from a blackboard, are not encoded appropriately. State of the art video compression relies on dropping out the higher frequency parts of the images resulting in the loss of sharp edges. Either content becomes unreadable, blurry or the video stream consumes huge bandwidth.

Looking instead for established teaching techniques, one finds the chalkboard has been an unmatched teaching tool for ages in many disciplines. Learners can see how ideas are developed rather than being overwhelmed with final results. This inspired the development of the described system called E-Chalk (WWW).

A good chalkboard lecture should automatically result in a good e-learning lesson. The goal is to preserve the pedagogical advantages and the easy handling of the traditional chalkboard, while extending its reach to distance learning. The system tries to enhance teaching quality in the classroom by allowing the instructor to integrate multimedia elements. During classroom teaching the lecturer works directly on a pen-active display or uses a digitizer tablet. At the same time, the lecture is being saved and transmitted live over the Internet with negligible additional effort. The
system transmits audio, video, and the animated board image of the lecture (illustrated in Figure 1). Remote students only need a Java enabled Internet browser without additional plugin. They can also obtain a print out of the lecture, since a PDF file is generated as a static copy of the board content. For an optional postproduction of lectures, a program called Exymen has been developed. Among other functionalities, it allows one to change the audio track on a recorded lecture and to fix errors in the board content.

2. METHODS FOR LECTURE RECORDING

The following paragraphs present a small overview of systems currently used for creating distance education classes.

2.1 Video conferencing systems

Lecturers wanting to transmit a class often use a video conferencing solution. However, video conferencing systems have not been created for teaching explicitly. Their conception assumes a symmetric communication and relies on all participants having equivalent hardware. Great effort is spent transmitting audio and video, but convincing concepts for the transmission of teaching specific content, such as board drawings, are not available.

2.2 Internet video streaming systems

Educators often rely on conventional video encoders and players, two of many examples are Webcast Berkeley (WWW) and iLectures (WWW). The main scope of commercial encoders, like Windows Media Encoder, RealVideo, or Quicktime, is the transmission and archival of audio and video data. Sometimes they include the synchronized display of presentation slides. Of course, the latter requires postproduction efforts. As described above, video encoding itself is not suitable for the display of slide or board writings. Using a naive recording setup these systems produce poor audio and video recordings from live lectures as their codecs assume a clean signal. In practice, one needs high quality sound equipment and technical staff to eliminate audience noise, reverberation effects, changes in illumination, etc.

2.3 CSCW tools

Several tools for working distributedly on a shared screen are available. Many digital whiteboard hardware comes with such a computer supported collaborative work tool. They are neither designed for teaching nor for production purposes but for desktop sharing with annotations. If they support archiving, they save a static screenshot.

2.4 Lecture recording tools

Several applications record a presenter’s desktop with annotations, audio, and video. See for example LecCorder (WWW), Lecturnity (WWW), Camtasia (WWW), Classroom 2000 (WWW) and Abowd (1999), or AOF (WWW). Using the computer desktop as a lecture medium has severe
disadvantages. The idea of the desktop metaphor is to be a virtual extension of the physical desktop, meant to be used with a mouse and a keyboard by one single person and not to be shared with an audience. The universality of this paradigm turns into a drawback in the lecturing situation. For example, technical details such as browsing through the local file system or error messages are visible to everybody. This does not only put pressure on the lecturer but is also distracting for learners.

Consequently, recording slide presentations predominate, hiding the desktop. While this approach improves the situation, the authors think slide shows are still not adequate for domains of teaching, where complex trains of thoughts are to be developed by the instructor and followed by the students, like in science. Another difference between presentation and lecture is, that presentations have to be prepared in detail and concentrate on results. Many professional lecturers are able to simply walk to the chalkboard and start up a spontaneous talk with a high degree of interaction with the learners.

Most lecture recording tools require the remote learner to install a special receiving software, usually designed as a browser plugin. This introduces a psychological barrier for first time users – compare for example Nielsen (1999). Moreover, remote learners often do not have the skills or even the permissions (for example on campus computers) to install such a client software.

3. THE E-CHALK SYSTEM

3.1 In the lecture room

The main objective is to present teachers with the environment they are familiar. The lecturer should be able to step into the classroom and start teaching on the board without extra effort.

Having started E-Chalk, the system’s user interface metaphor changes from a computer desktop to a chalkboard. The computer screen becomes a display for more than one person. The mouse is replaced by a pen-like input device and the use of the keyboard is avoided as much as possible (for concrete hardware solutions – see section 4). The software transforms the screen to a black surface where one can draw using different colors and pen thicknesses. The board can be scrolled up and down vertically, providing the lecturer with a virtual unlimited surface to write on. Instead of using a desktop-style scrollbar, two scroll points are provided at the top and at the bottom of the screen (see Figure 2). The user grabs the board at a scroll point with the pen and drags the board up or down.

The system allows the user to paste images from local hard drive or the Internet. Mathematical requests can be processed using an interface to computer algebra systems (such as Mathematica by Wolfram Research or Maple by Waterloo Maple, Inc), partially by using a handwriting recognition, see section 3.1.1. Also any CGI script in the web delivering text or pictures can be queried.

All these actions on the board are tracked. The development of the board content can be viewed by a remote learner, both as a live transmission and as an asynchronous replay. The voice of the lecturer can also be recorded. These two data streams capture already most of the teaching substance. The distance learner is provided with a live script where teacher’s side notes are not lost. Optionally, a video stream of the instructor can be used to give the remote lesson a more personal touch.

The system does not require the user to explicitly trigger a save. Everything is automatically stored for web browsers. E-Chalk can also be configured to store the lecture in a database or a learning management system. The entire software has been written in Java and runs on Linux, MacOS X, and MS Windows platforms.

3.1.1 Handwriting recognition

As mentioned above, keyboard typing should be avoided in the board metaphor. Its usage interrupts the lecturer’s workflow. As a result, a handwriting recognition was included in E-Chalk right from the very beginning (cf. Rojas et al., 2001a, 2001b; Friedland et al, 2003). While the early version could only handle simple arithmetic expressions, it has now moved to more complex mathematical formulas, see for example Figure 4.

Figure 3 Above: Main horizontal baseline and clusters of symbols. Below: Final tree of spatial relations
When a set of strokes is recognized as being grouped into a symbol, it is preprocessed and classified. A special symbol is reserved to mark the end of an expression. It is a tick symbol, reminding one of the symbol printed on the enter key of usual computer keyboards. If the classification result gives as output the “end” symbol, the system analyses the complete list of recognized symbols. Two different groups of symbols are recognized by the program. The first one consists of the digits 0 to 9, the arithmetic operators $+,-,\times,\div,\sqrt{}$, the parenthesis and the ‘end’ symbol. The second group is formed by the variables $a, b, c, m, n, x, y, z, \theta$ and $\Delta$, the constants $e, \pi$ and $\infty$, and the operators $\int, \Sigma, \Pi, \partial$ and the differential operator $d$ in the integral. If an external computer algebra system is connected to the E-Chalk system, all the symbols are recognized and passed to the algebra system, otherwise only the first group is recognized and then processed by a basic calculator included in E-Chalk.

The construction of the formula is made following two main steps: recognition of symbols and construction of the hierarchical structure in the mathematical expression. The recognition of online characters is done using Support Vector Machines (see Tapia and Rojas, 2003b), a recent technique for classification and regression based on the research of Vapnik and Chervonenkis (see Vapnik, 1998). The structure of the mathematical expression is determined as follows: Mathematical notation can be described as a hierarchical structure of nested baselines, which represent a horizontal arrangement of symbols in the expression. Exploiting the left-to-right reading of mathematical expressions, the main baseline is constructed and clusters of symbols not belonging to the main baseline are found using a minimum spanning tree construction based on symbol dominance, making an analysis on the proximity of symbols (see Figure 3). Symbols in the main baseline have pointers to the clusters, depending on the mathematical relation (above, below, right, superscript, subscript, subexpression) they satisfy. We apply recursively the method on clusters as long as no more symbols are left when the horizontal baseline is constructed (see Tapia and Rojas, 2003a).

### 3.1.2 Audio and video streaming

Early versions of E-Chalk used the World Wide Radio (WWW) system (see Friedland et al., 2002) to stream and archive the voice of the lecturer. This was similar to the common approach for on-the-fly streaming and recording of university lectures: software defined radio systems combined with video and slides. World Wide Radio was designed for streaming web radio and its principal design can be compared to other approaches, like RealAudio, Quicktime, or Windows Media Player (Manhart, 1999). The main difference is that WWR is implemented in Java. As a result it can only use technology that exists on every platform, operating system specific codecs for example cannot be integrated. On the other hand, combinability between standard Internet streaming systems is missing, for example, if one wants to combine a video conferencing system with E-Chalk. Usually, several streams are combined by just starting different applications. Of course, no synchronization then exists between the streams.

E-Chalk now uses a system where any streaming server is modeled as a flow graph, Figure 5 shows an example. The graph consists of five basic types of nodes: Sources, Targets, Forks, Mixers, and Pipes. Technically, any component that wants to live inside the graph becomes a node by inheriting one of these five superclasses. The graph that glues these components is described by an XML file. Nodes are described via general properties, for example, to tell the system to select some audio codec that compresses down to a certain bandwidth. The system then looks for an appropriate codec, first locally and then in the Internet. The structure of the graph can be changed and the nodes can be updated while the system is running. All data is being synchronized automatically. This allows clients to let the server be updated on the

![A simple streaming server graph](image)
fly to match their requirements, instead of forcing the client to load an updated module. For example, nodes for both WWR and Windows Media Player exist. When a client connects with either Windows Media Player or with the Java based client for a live connection, the E-Chalk streaming system updates itself and loads the appropriate modules.

All the nodes are realized as services inside an environment, standardized by OSGi (WWW). The mechanism originally comes from the field of ubiquitous computing and specifies how to load, update, and delete software components from the Internet, while a system is running (OSGi, 2002). E-Chalk uses the Oscar/OSGi implementation (Hall and Cervantes, 2003).

### 3.2 Optional postproduction

Exymen was created as an editing tool for arbitrary media formats (Friedland, 2002b). It offers an open programming interface (API) which allows to extend the editor for any multimedia format and filtering effect. The extension mechanism is based on Oscar/OSGi (see section 3.1.2).

Among the formats implemented are those for editing E-Chalk lectures, as shown in Figure 6. This allows to postprocess recorded lectures. A special problem of the board stream is that events depend on each other in both time and space and cannot be edited naively. The implementation takes care of the resulting constraints (Friedland, 2002a). When the E-Chalk streaming system introduces a new component (see section 3.1.2) it is also automatically used for editing in Exymen, as they use a compatible component management and update mechanism.

Another extension of Exymen allows the creation of animated web slide shows with audio tracks. See the Giove Project (WWW) for an example.

### 3.3 Distance learning

When remote students open E-Chalk's generated webpage of a given course with a browser, replay starts in the form of self synchronizing Java Applets. One Applet is started for every data stream present: board, audio, and video. Another Applet, a control panel, is provided for navigation in archived lectures (see Figure 7). All these Applets run in a standard Java enabled browser, without requiring the user to download a plugin. As another advantage this solution is completely platform independent.

The audio system uses lossy compression and buffering to guarantee interruption free transmission. The required bandwidth for the transmission of audio and dynamic board content is up to 64 kbps, depending on the selected audio quality. The network traffic generated by the board content is negligible compared to the traffic needed by the audio signal, since the board uses a vector format. Using a video stream requires further 64 kbps. For the compression of the video signal a simple codec is used, based on difference images and JPEG. A static copy of the final board image as Adobe PDF file is also included for the students to print – see Figure 8.

### 4. USE CASES

To use the E-Chalk Software in the classroom, one...
needs a pen based input device and a wide display. The display should offer good contrast, so that the visual quality can be compared to a real chalkboard, e.g. one does not want to darken the room for the lecture. Mainly, the following device configurations are in use:

- **Digitizer tablets or tablet PCs with LCD projector**
  The lecturer writes on a tablet while the computer screen is projected against a wall. Digitizing tablets are comparatively cheap and easy to transport. The teacher can look at the audience while writing, if a tablet with integrated display is used, which also eases hand-eye coordination.

- **Digitizing whiteboards**
  Several companies distribute digitizing whiteboards. These are wide, perpendicular mounted digitizing tablets (up to 8” diagonal). The screen content is displayed on the surface by an LCD projector.

- **Retro projectors with pen tracking**
  The advantage of using a retro projection system as wide display device is that nobody interferes with the projection beam. Contrast and luminance being much better than those of an LCD projector they are usable without darkening the room. Disadvantages are their heavy weight and the high purchase costs.

Having many students in a lecture room, a very big display surface is required. One can use a digital whiteboard or a digitizer tablet as writing surface plus an extra projector that projects the board content widely. This way, board content is even better visible than on a regular chalkboard. The Technische Universität Berlin uses this setup regularly – see Figure 9.

For smaller seminars one can use a setup with several digitizer tablets, enabling students to interact on the board from their seats. In the case shown in Figure 10, the geology lecturer uses a rear projector and the students use small digitizer tablets to work on geographical maps.

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

The Freie Universität Berlin also used E-Chalk in combination with videoconferencing systems to have audiences in different locations at the same time. The chalk content is sent parallel to the video conferencing stream (see Figure 11). This enables students to follow remote chalkboard lectures and communicate with the instructor.

It is also possible to give a lecture at home and present it later (see Figure 12). School teachers found this a practical feature because they can easily create classes for the students to see at home.

5. EXPERIENCES AND EVALUATION

Since the summer term 2001 the computer science department of the Freie Universität Berlin uses E-Chalk for courses regularly. Since the winter term 2002 the mathematics and physics departments of the Technische Universität Berlin has equipped eight lecture halls and seminar rooms with E-Chalk. In the summer term 2003, about 1100 students were taught with E-Chalk at these two universities. The authors counted about 700 installations of E-Chalk world wide (as of November 2003), 50 of them are known to be used regularly. A field study has started to evaluate the use of E-Chalk and its improvement for classroom teaching (Schulte, 2003). The results are summarized below. The Berlin school department is evaluating whiteboards using E-Chalk in Berlin elementary and secondary schools. Within the project ‘Computer in die Schulen!’ (CidS! (WWW)), twelve schools were equipped with electronic boards since early 2003. One of them is shown in Figure 17.

5.1 Evaluation

5.1.1 Methods

The evaluation was constructed as a field study
under real life conditions. Its emphasis lies in the explorative description of leading questions, such as the usage and acceptance of the software, as well as possible effects on the students’ motivation for studying. An examination has been conducted to find out effects on students’ exam results. These aspects were evaluated throughout the summer term 2003 in six selected lectures at both, the Technische Universität Berlin (TU Berlin) and the Freie Universität Berlin (FU Berlin).

For some of the leading questions the development of answers through the term was examined. 595 questionnaires were evaluated and 52 students were identified to have answered the questions twice, in the beginning and in the close of the term. Their responses were examined for changes in their attitudes.

To find out E-Chalk’s influence on exam results, students were asked for their usage intensity for preparation. Some lecturers were selected by chance to be interviewed. One lecture used a learning management system giving the evaluator statistics on the student’s access on E-Chalk.

### 5.1.2 Findings

At the TU Berlin, students preferred sitting in the lecture hall over remote replay. Still, the remote usage at both universities intensified during the term, see for example Figure 13. The rising intensity indicates students’ preparations of their upcoming exams.

However, no significant correlation between exam results and usage could be found (see Figure 14). In all user categories almost the same grade has been achieved. The evaluation report explained this with influence of external factors. The author of the report suggests further examination by forming two groups with the same external conditions differing only in the usage of E-Chalk.

At the TU Berlin courses, the printable PDF was preferred to the replay of lectures by most students. The cause is that no audio signal was recorded at the TU Berlin due to infrastructural problems with their audio equipment. Students of the FU Berlin used the PDF and the replay on an equivalent level. A small, but not statistically significant tendency exists, that students reduce copying board contents compared to regular courses (see Figure 16).

At the TU Berlin both mobile and fixed digital whiteboard installations were tested. Experience...
showed mobility is not desirable. Even a slight, possibly unintentional move, requires the whiteboard to be recalibrated.

The usage of E-Chalk did reveal neither positive nor negative effects on the students’ motivation to prepare for the lecture. Quality of the software was judged positively by the students. Didactic quality of the courses had been perceived well compared to regular courses (see Figure 15). Students welcomed the extra flexibility.

Lecturers’ skills regarding the software improved noticeably during the term, as shown in Figure 18. Lecturers needed between two and four lectures to get fully accustomed. The evaluation report judges this as an indication for the easy handling of the software.

5.1.3 Results and interpretations
Recorded lectures are also useful for students not being able to be present in the classroom for different reasons, for example scheduling collisions. The most frequent use of recorded lectures is for exam preparation. The live transmission of the lecture can also help to relieve classrooms. However, experience showed that, compared to replay of archived lectures, the demand for live transmissions is marginal. The following points summarize further evaluation results:

- Overhead work to use the system for lecturing is limited to the start of the term for setup.
- The lecturer can easily integrate material from former terms.
- Traditional chalkboard skills directly map into good E-Chalk lectures.
- In practice the use of plain drawings and writings predominates. Features like the integrated computer algebra system or calling CGI scripts are used rarely.
- If audio has been recorded with the lecture, students use both, the E-Chalk replay and the PDF printout.

Of course, one should not think that the system increases the quality of teaching just by its existence. Teachers have to use it properly and students still have to study.

6. ONGOING DEVELOPMENT

Producing distance lectures with high fidelity audio requires additional man power. This is to be substituted by intelligent software. Usually a high quality recording and transmission of the lecturer’s voice requires support from two kinds of persons:
System administrators who set up and combine the required components (such as codecs, server components, and web sites) and audio technicians who control the quality of the recording. The self-organising streaming system described in section 3.1.2 already takes over a big part of the administration workload. Section 6.1 describes the approach for providing a software audio technician. Section 6.2 presents the authors’ current work to optimize the usage of the video image in E-Chalk.

6.1 Studioless audio recording

Lecture halls and seminar rooms are not audio recording studios. Therefore it is not possible to produce professional quality recordings by just plugging a microphone into a soundcard and starting the lecture. Recording studios have a lot more equipment and qualified audio technicians are always present. The system’s audio recording assistant helps to prevent the most common problems by giving direct feedback to the instructor, for example showing a warning when the remote microphone is out of battery. The more sophisticated task is to develop software to control the input gain and to use proper realtime filters for achieving high quality recordings.

6.2 Transmitting gestures

E-Chalk lectures which include a video of the instructor share a psychological problem with conventional distance lectures consisting of slides plus video stream. Although every human being only has one center of attraction (see Baar, 1988), the attention of the remote student is demanded by two areas of the screen: the video window and the board or slides area. Hence a project has been started to separate the video image of the lecturer from the background. The image of the instructor can then be laid over the board, creating the impression that she or he is directly working on the screen of the remote student. Mimics and gestures of the instructor are now appearing in direct relation to the board content. The image of the lecturer can be made semitransparent or even turned off (see Figure 19).

7. SUMMARY

With the system presented here it is possible to produce distance lectures as a by-product of classroom teaching. The distance lectures are not substituting classroom teaching but supporting it.
Students are helped to rework the materials with a living and active script. The remote student does not have to spend great technical effort to receive the lecture. Only a browser is used and no special software has to be installed. All substantial information in the form of audio and dynamic board image can be received with low bandwidth requirements.

The board is a new GUI metaphor. At the time being, the desktop is the dominating user interface. This metaphor, however, is designed for the small, personal screen that integrates in the physical writing table. Even the pen computing approaches, which have become popular recently, are considered only for personal displays. During the teaching situation, where a wide display is observed by a greater audience, the board is the proper metaphor. This way, the relation between teaching tool, teacher, and students is preserved, as it proved to be valuable for centuries. The audience can track the instructor developing the subject on the board. The technical implementation of the teaching device is formed by the pedagogical needs, instead of letting the device be purely driven by the technical development.

Project members

Prof. Dr. Raúl Rojas conceived the E-Chalk system and is head of the project.

Gerald Friedland and Lars Knipping are researchers at the department of computer science at FU Berlin. They developed the E-Chalk system.

Joachim Schulte is a student of communication sciences and performed the evaluation.

Ernesto Tapia is a PhD student at the FU Berlin and has developed the online handwriting recognition.

NOTES

1. For example, Lecturnity (WWW), AOF (WWW) and Camtasia (WWW) require proprietary player software. LecCorder (WWW) uses signed Java-Applets for replay.

2. Actually, the system can be configured for different background colors. In practice, black is preferred because having the content shining instead of the background is less straining on the eyes.

3. So far, the authors experimented with an Oracle database and the learning management system Blackboard.

4. This task requires a developer to overwrite ten or less methods for building a wrapper to a streaming service one wants to integrate.


6. The Applets need only Java 1.1, to avoid the requirement of a Java upgrade for the browser, and they need not be signed.

7. At the Freie Universität Berlin, E-Chalk was evaluated in a computer science lecture on Neuronal Networks. At the Technische Universität Berlin E-Chalk was evaluated in the courses: Calculus II for Engineers, Introduction to Numerics, Linear Algebra for Engineers, Numerics for Engineers, and Introduction to Physics for Engineers.

8. The FU Berlin used the learning managment system BlackBoard (WWW).

REFERENCES


AOF (WWW) http://ad.informatik.uni-freiburg.de/aof, visited 11 November 2003

Webcast Berkeley (WWW) http://webcast.berkeley.edu, visited 11 November 2003

BlackBoard (WWW) http://www.blackboard.com, visited 11 November 2003

Camtasia (WWW) http://www.techsmith.de/products/studio, visited 11 November 2003

CidSi (WWW) http://www.cids.de, visited 11 November 2003

E-Chalk (WWW) http://www.echalk.de, visited 11 November 2003

Classroom 2000 (WWW) http://www.gatech.edu/fce/eclass, visited 11 November 2003

Giove Project (WWW) http://www.giustiniani.org, visited 11 November 2003

iLectures (WWW) http://ilectures.uwa.edu.au, visited 11 November 2003

LecCorder (WWW) http://www.leccorder.com, visited 11 November 2003

Lecturnity (WWW) http://www.lecturnity.com, visited 11 November 2003

OSGi (WWW) http://www.osgi.org, visited 11 November 2003


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Joachim Schulte is a student of Communication Sciences, Psychology and Journalism at both the Freie Universität Berlin and Technische Universität Berlin. He has recently finished his master thesis, “Evaluation of the usage of ‘E-Chalk’ in university lectures”.

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