2006-1326: INTELLIGENT CHALK-SYSTEMS FOR MODERN TEACHING IN MATH, SCIENCE & ENGINEERING

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Intelligent Chalk-Systems for Modern Teaching: in Math, Science & Engineering Areas

Abstract

This article describes a software system that transforms an electronic whiteboard into a teaching tool simulating a traditional chalkboard. In addition to writing and drawings, the electronic chalkboard handles a wide range of multimedia enhancements. These may be used to enliven the lessons by visualization, allowing the system to surpass the didactic potentials of the traditional chalkboard. The system records all actions and provides both a live transmission and a replay of the lecture from the web. Systematic evaluations from regular use at two universities are presented.

1. Introduction

University teachers have often come to rely on the wide-spread use of slideware (such as Microsoft PowerPoint) for additional motivation of their students by providing a modern touch to their lectures. These tools allow the teacher to easily produce materials with a professional, polished look and facilitate simplified publishing, both electronically or as hardcopies. Even more importantly, once created the lecture materials can be quickly and easily reused.

In contrast, the employment of slideware products in teaching has also been heavily criticized[6]. These products have originally been developed for presentation purposes. It has been argued, that they are well-suited to the task of "selling" a product or idea while they tend to be inadequate for presenting complex arguments.[16, 17]

Also, the human brain can be easily overloaded by the sensory input that eLearning and multimedia technology is capable of generating[5]. Even though these tools can be used to give a well-structured and easy-to-follow lecture when correctly employed, they do tend to foster a tendency to overwhelm learners with an overly rapid presentation of information. The lecturers, naturally, posses a deeper understanding of the subject and often tend to progress through the lecture at a pace too fast for their students to follow. Traditional teaching using a chalkboard imposes a natural limitation on the pace of the lecture that is overcome through the use of slideware. Also, classes given with slideware tend to be far less flexible and spontaneous than more traditionally presented ones. To use the words of a university lecturer, "*PowerPoint sucks the life out of a class*" [2].

Some approaches try to address this situation by adding annotations to slides. Office XP now features annotation tools in PowerPoint. Classroom Presenter streams a combination of PowerPoint slides and freehand "inking".[3] The "eClass" (later "Classroom 2000") software is an early example of recording snapshots of annotated slides and electronic whiteboard drawings for distance teaching purposes.[1]

The main drawback of the slideware approach lies in being technology-driven, focusing on utilizing the technological possibilities offered by computers and multimedia technology today, instead of being guided by the demands of teaching. Investigating established teaching techniques, one finds that the old-fashioned chalkboard is still unsurpassed as a teaching tool due to its intuitive use and unmatched flexibility. The board ensures that information stays available, providing context for further discussion. The learners can see how ideas are developed rather than being overwhelmed with final results: they are supported in following the conceptual process. The teacher is slowed down to the speed of his or her handwriting, giving the students time to follow the lecturer's train of thought.

Compared to the use of prepared slides, the "chalk and talk" approach results in a much more flexible teaching style. Working on a chalkboard supports creative thinking, illustration, and sharing. Board drawings can be used to draw attention to details using circles, arrows, underlines, checks, groupings, etc. The inherent impreciseness and vagueness of freehand drawings holds extra information. Given these outstanding qualities for teaching, it comes as no surprise that the chalkboard is still so popular for teaching in many disciplines, especially for subjects where complex reasoning has to be taught, such as mathematics, engineering, and the natural sciences.

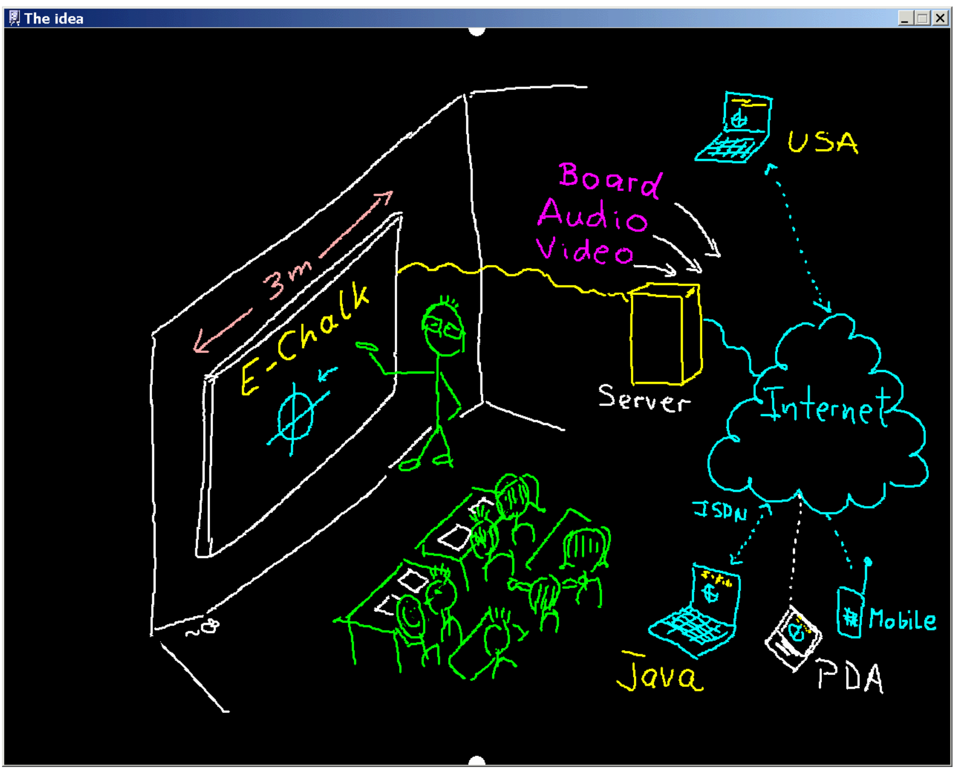

Figure 1. eChalk's idea as an eChalk sketch

These considerations inspired the development of a system called eChalk.[7, 10, 12] Ideally, lecturers are enabled to teach with the system like a regular blackboard. During classroom teaching, the lecturer works directly on a pen-active wall display. While the eChalk interface is based on the metaphor of the simple chalkboard, it is enriched by a wide range of multimedia enhancements. These may be used to enliven the lessons, allowing eChalk to surpass the didactic potentials of the traditional chalkboard.

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

2. The eChalk System

2.1. Hardware Setups

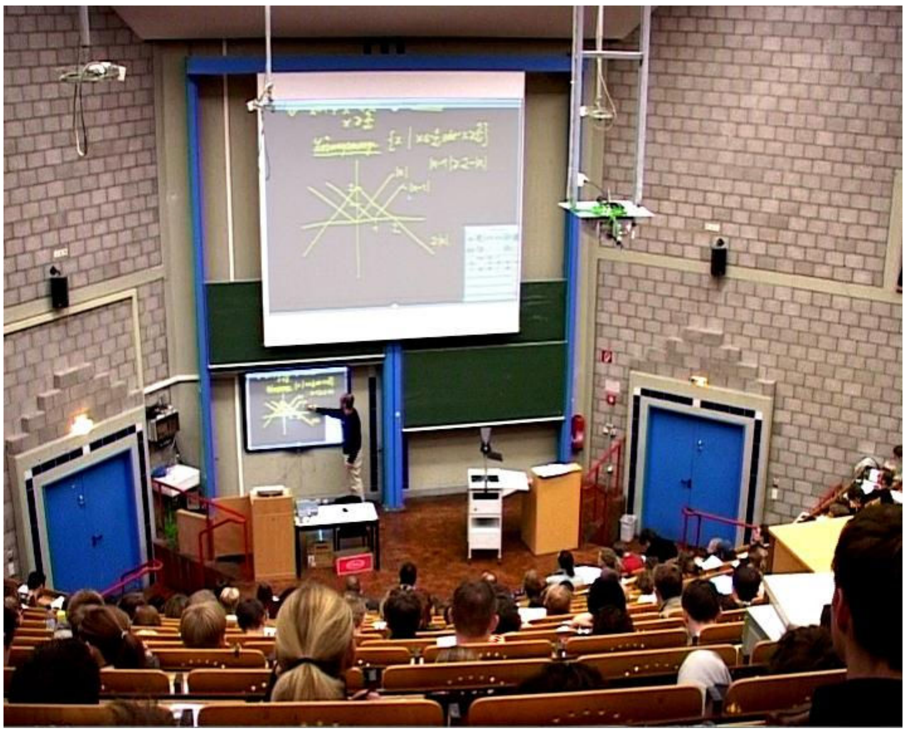

Figure 2. Mathematics lecture at Berlin University of Technology using a digital whiteboard and an extra projector

In order to use the eChalk Software in the classroom, one needs a pen based input device and a wide display. Mainly, the following alternative 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 by a beamer. Digitizing tablets are comparatively affordable and easy to transport. The lecturer can face the audience while writing, if a tablet with integrated display is used, supporting interaction with the audience through eye contact. As an additional advantage, this solution is highly mobile.

- **Digitizing whiteboards**
  Several companies distribute digitizing whiteboards. These are wide, vertically mounted digitizing tablets (up to 80” diagonal). The screen content is displayed on the surface by an LCD projector. As an advantage, the lecture is displayed in the same spot as it is developed further focusing the attention of the audience. In addition, many teachers prefer the wider movements of working at the board, keeping them more active than in the tablet setup. As a drawback, the lecturer will often cast shadows on the projection. Even slight movements of non-fixed whiteboard or to projector require the pen settings to be recalibrated. Also, when instructors turn to the audience, they might look into the projection beam.

- **Retro projectors with pen tracking**
  The advantage of using a retro projection system as a wide display device is that nothing interferes with the projection beam. Because contrast and luminance are much better than those of an LCD projector they are usable without darkening the room. Disadvantages are their heavy weight, bulkiness, and high unit costs.

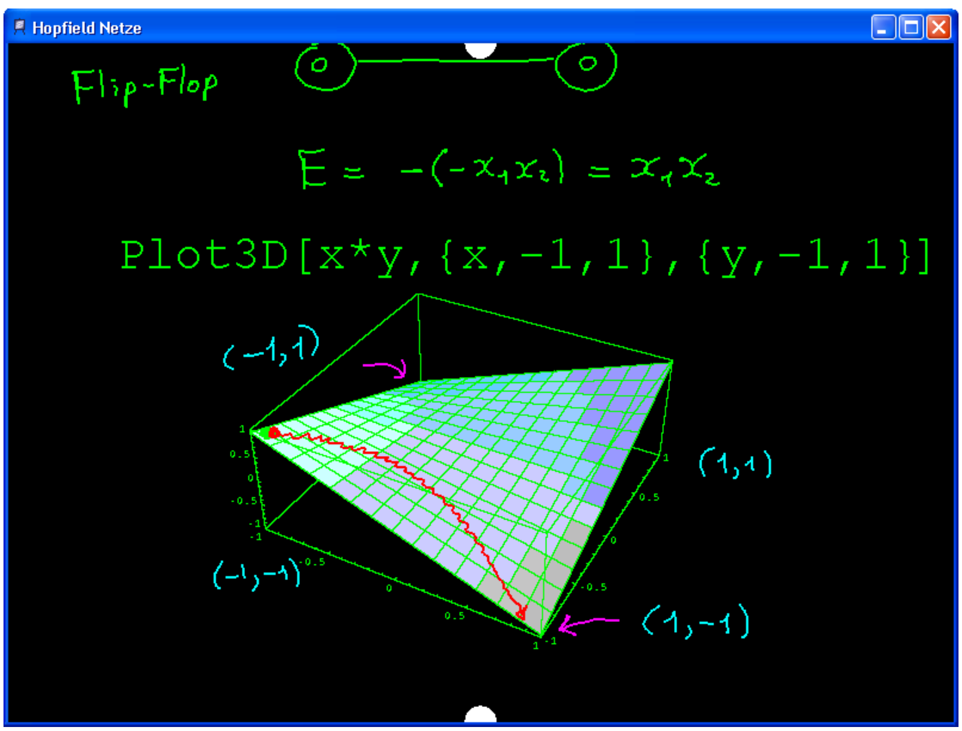

Figure 3. Lecture containing a plot from a computer algebra system

All of these setups are restricted by the limited size of writing area and the low resolution of the displays. While the described digitizer hardware is theoretically capable of recognizing the pen’s location far beyond the accuracy of the human hand, the resolution is limited by the screen resolution of the projector and the controlling computer’s graphics card. However, organic displays might solve these problems as very wide, high-resolutions screens are expected to be available within the next few years[4].

2.2 In the Lecture Hall

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

Having started eChalk, 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 wherever possible. The software transforms the screen to a black surface where one can draw or write using different colors and pen widths. The board can be scrolled up and down vertically, providing the lecturer with a virtually unbounded surface to write on. Instead of using a desktop-style scrollbar, two *drag handles* are provided at the top and at the bottom of the screen (see Figure 3). The user grabs the board at a drag handle using the pen and drags the board up or down.

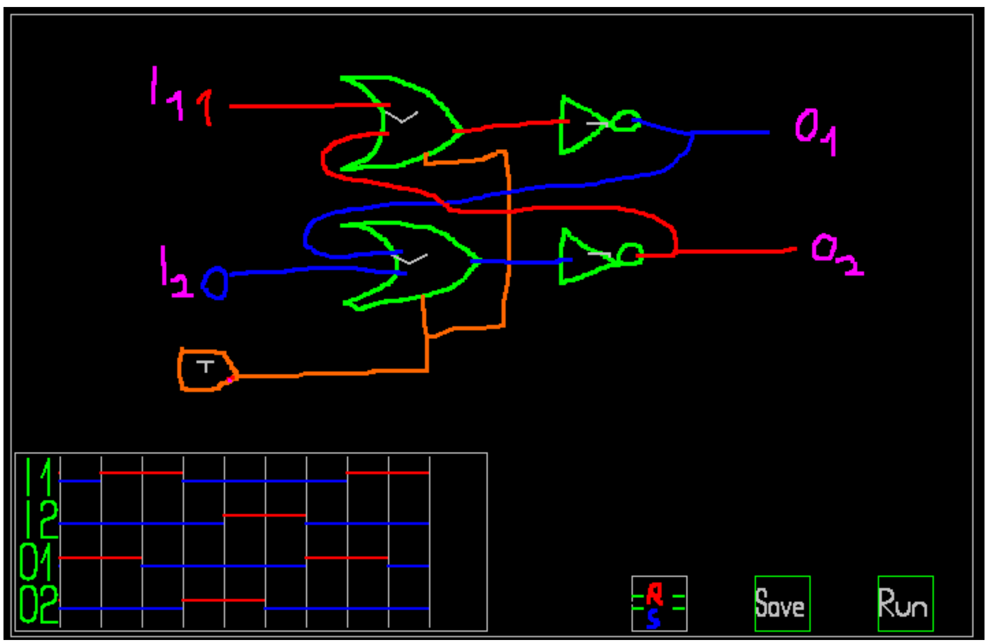

Figure 4. Simulating a clocked RS Flip-Flop

The lecturer may embed images from the web or the local storage devices and annotate them. As a much more sophisticated feature, computer algebra systems (such as Mathematica by Wolfram Research or Maple by Waterloo Maple) working in the background can be queried for their numeric or symbolic results or even for function plots, all seamlessly integrated into the board drawings (see Figure 3). A mathematical formula recognition allows these requests to be input conveniently in handwriting, including such complex objects as differential operators, integral symbols, vectors, and matrices.[11, 15]

The lecturer can also send queries to dynamic web services (CGI scripts) returning text or pictures. Interactive Java applets can be run on the board to provide visualizations for abstract topics and concepts. Alternatively, custom eChalk modules called Chalklets can be used. These are controlled by means of strokes of the pen on the board and return drawing strokes themselves, preserving the board-like look and feel. For example, a logic circuit simulator[13] recognizes sketches of digital circuits and runs a simulation, color-coding the wires to indicate high or low voltages, as shown in Figure 4.

The system does not require the user to explicitly trigger a save. Everything is automatically and continuously stored for viewing through standard web browsers. The entire software has been tested on Linux, Mac OS and MS Windows platforms.

2.3. Remote Usage

When remote students open the automatically generated web page 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. An additional applet, the control panel, is provided for navigation in archived lectures (see Figure 5.) All these applets run in a standard Java-enabled browser, without requiring the download of a special plug-in. As another advantage, this solution is completely platform independent.

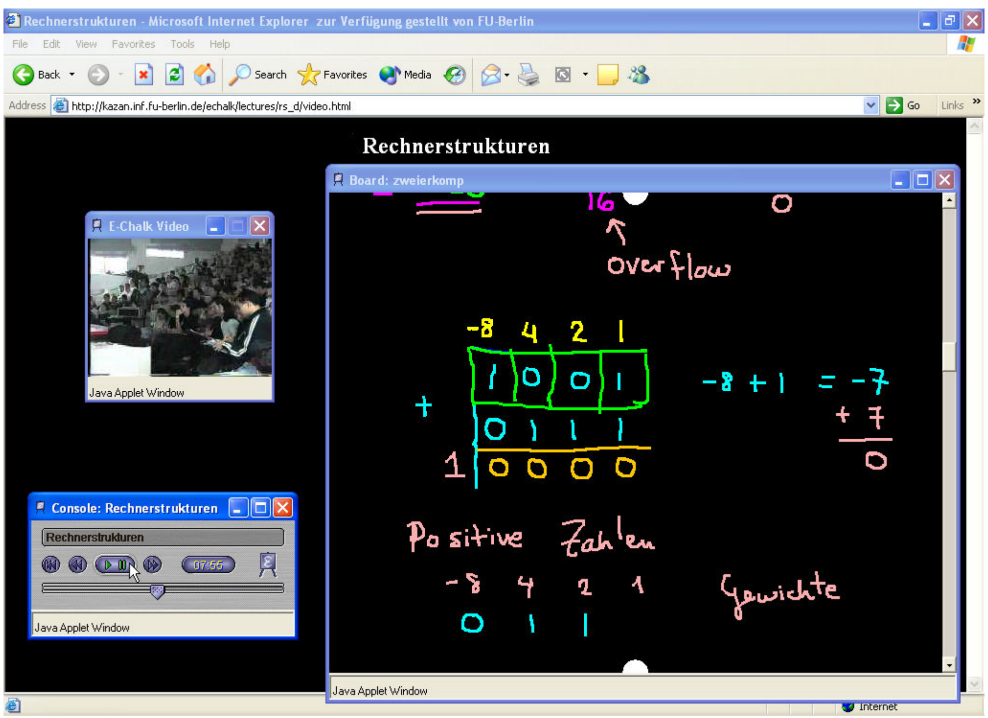

Figure 5. Replay of a recorded eChalk lecture as seen in a browser

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 does not surpass 64kbps

A printable, static copy of the final board image is also included as an Adobe PDF file (see Figure 6).

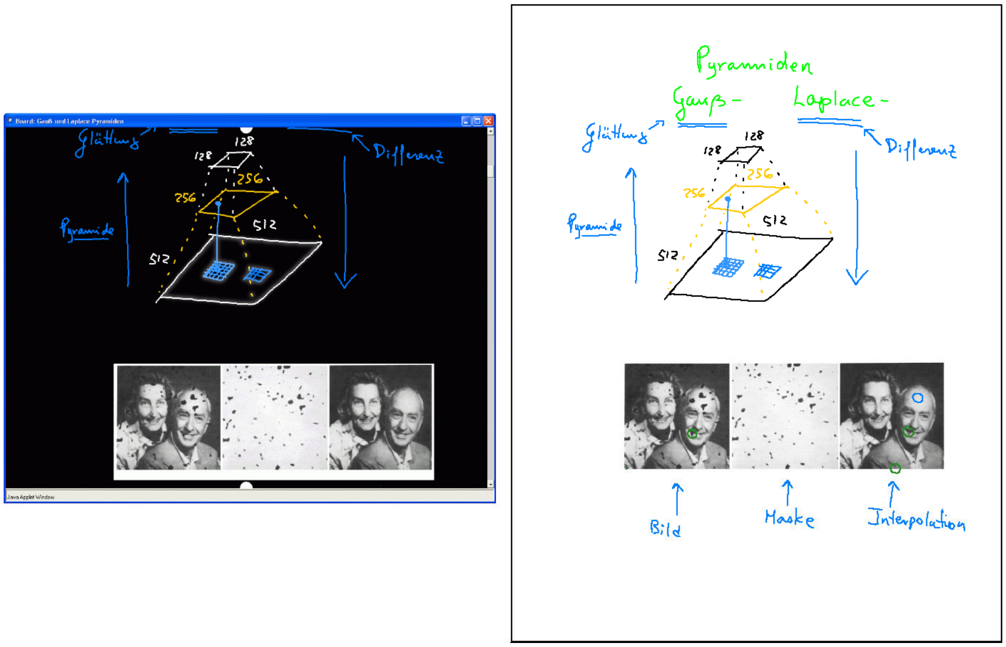

Figure 6. An eChalk lecture replay and the corresponding PDF page

3. Evaluations

A number of field studies have been conducted in the course of university courses to evaluate the use of eChalk, its impact on teaching, and its acceptance under real-life conditions. These studies were arranged by media psychologists from the Freie Universität Berlin and Technische Universität Berlin (Schulte, Issing and Hendricks). The courses included lectures and exercises on mathematics for engineers, physics for engineers, computer science as well as seminars on cartography. For computer science courses, replays with audio and PDF transcripts were provided. The cartography seminars used the system for classroom teaching only. The engineering courses provided replays without audio recordings and PDF transcripts.

During the 2003 summer term, six eChalk courses were evaluated.[14] Data gathered included 595 full questionnaires, filled out at the beginning and end of the term, 893 short questionnaires filled out during the final exam, interviews with the six instructors, and Web access analysis for one of the courses. In a second study conducted during the winter term of 2003/04, 303 questionnaires from nine eChalk courses were evaluated.[9] In the following the main findings are presented. A detailed summary of these studies can be found in.[12]

3.1. Findings from Student Questionnaires

Adopting eChalk in teaching did reveal neither positive nor negative effects on the students' motivation to prepare for the lecture. Didactic quality of the courses was perceived positively compared to regular courses. Students welcomed the extra flexibility in learning, both for increased independence in time and in location.

The students were asked to judge the impact of the system on their studies, whether it helped in or complicated learning. The answers showed a clearly significant tendency towards a positive impact.

About half of the students (46.8%) reported using the eChalk materials regularly for revising the classes. The average time spent revising including the “zero minutes users” was 19 minutes per week. Considering only those students who actually use eChalk for revision, the average was 40 minutes, the median 30 minutes. However, these figures should not be taken too literally, as they display a high degree of variance.

Asking students about the amount of note-taking in eChalk classes compared to regular classes yielded results differing between the two studies. The first study showed a small tendency (below statistic significance) of students reducing the amount of note-taking compared to regular courses. According to the second one, about 60% of students were taking at least as many notes in eChalk classes as in conventional classes.

The short questionnaires coupled with the exam in the summer term study were used to compare exam results and eChalk use. However, no significant correlation between exam results and eChalk use could be found. In all user categories almost the same grade has been achieved. [14]suggests further examination by forming two groups with the same external conditions differing only in the use of eChalk.

The first evaluation also examined the students’ opinions on the quality of the system. The answers concerning the visual impression showed a slight tendency towards a favorable opinion, with no significant differences between classroom teaching and replay. The acoustic quality of the instructor’s voice, however, received below-average ratings for the replay. This result was a major motivation to enhance the audio recording quality in eChalk by the approaches described in[8]. Despite the shortcomings in audio quality, the overall quality of the system was clearly seen as positive, both in classroom teaching and in replay. Using eChalk in the evaluated course received above-average marks from 73% of all students.

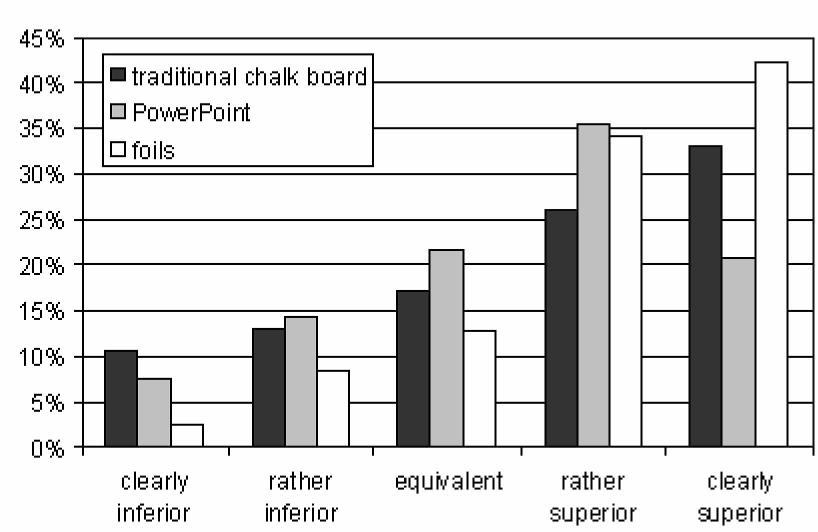

Figure 7. Students’ opinions on teaching with eChalk compared to using other types of lecturing tools: to traditional chalkboards, to PowerPoint, and to overhead slides

To compare eChalk with other teaching techniques, the students were asked to judge, in comparison, between eChalk-taught classes and classes using other teaching technologies. The comparison was made on courses using electronic slide presentations like MS PowerPoint, traditional chalkboard teaching, and overhead slides. eChalk was favored above all these three teaching media, with PowerPoint coming closest and overhead slides ranging last, see Figure 7.

Students' use of eChalk-generated material was found to be uncorrelated to the bandwidth of their Internet connection and their preferred type of browser. Thus, it can be assumed that eChalk recordings are equally usable with any type of connection.

The students were asked to provide comments on the advantages of the eChalk system, on its disadvantages, and on suggestions for improvements.

The most frequently mentioned advantage was a clear, readable board image, followed by comments on remote access, revision material, enhanced visualization through the use of applets and images, the elimination of the need to copy the board content, providing the learners with more time to concentrate on the content of the lecture. A few students also noted that the lecture was easier to follow with the system.

Commonly mentioned disadvantages include complaints about the visual quality of the board image, the relative size of the board, and the bad handwriting of the instructor. A likely cause for these shortcomings is the low resolution of the displays used, forcing the instructor to write larger letters for improved readability. See 2.1 for a discussion.

Almost all comments on possible improvements were requests for features which were already fully supported, but not used in the evaluated lecture.

3.2. Findings from Instructor Interviews

According to the lecturers interviews, the time needed by lecturers to get fully accustomed to the system, ranged between one and four lectures. [14]judges this as an indication for the intuitive handling of the software. The interviews also showed that most features beyond the basic writing features and use of images were rarely used.

The instructors' comments on advantages and disadvantages of the system were similar to the most frequent students' comments. In addition, they judged as positive that the teaching content of traditional classes needs no restructuring when presented with the system, enabling them to reuse their old materials. Some lecturers mentioned that they missed the small pauses introduced in traditional chalk lectures by the wiping of the board.

4. Summary

The evaluation confirmed the potential of eChalk as a beneficial and usable system for teaching. The additional burden required in using the software for lecturing is limited to the start of the term. The lecturer can easily integrate material from previous terms. Traditional chalkboard-related skills translate directly into skills for good eChalk lectures.

The system enables the user to produce electronic course materials simply as a by-product of classroom teaching. These are not meant to substitute classroom teaching but rather to support it. Students are supported in their revision of classes with a live and dynamic "transcript". Only a browser is needed for this and no special software has to be installed. All substantial content of the lecture including audio and dynamic board image can be received with low bandwidth requirements.

The system presented here not only tries to preserve the didactic potentials and easy handling of the traditional chalkboard. Its reach is extended to extensive use of new media and remote access, allowing to improve the teaching quality in mathematics and engineering education, and fostering understanding through interaction and visualization.

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