Chapter 8

Experiences and Evaluation

8.1 Case Studies

Practical experiences with full-fledged E-Chalk lectures have been gathered at the Computer Science department of Freie Universität Berlin since the summer term of 2001. At Technische Universität Berlin, eight lecture halls and seminar rooms of the departments of Mathematics and Physics have been equipped with E-Chalk since the winter term of 2002/03. In the summer term of 2003, about 1,100 students were taught with E-Chalk at these two universities [FKR03], and the numbers of students were similar in the following terms. About 800 installations of E-Chalk are in operation around the world (as of September 2004), with 80 of them reckoned to be used regularly. The majority of E-Chalk installations is found in university teaching, but also in practical-training instruction for technicians [55, 56] as well as in training scenarios at the Deutsche Bahn (German Rail) and the Bundeswehr (German Army).

The Berlin Department of Education initiated an evaluation of whiteboards using E-Chalk in Berlin elementary and secondary schools. Within the *CidS!* (*Computer in die Schulen!*) [10] project, twelve schools have been equipped with electronic boards since early 2003. One of these boards is shown in Figure 8.1. Feedback from personal contact indicated the highest levels of E-Chalk use in elementary schools, where writing and drawing on boards was used more frequently than in higher grades. However, the overall usage profile remained comparably low, as many teachers were reluctant to familiarize themselves with the technology. The evaluation report [Eul04] recommends training the teachers with the whiteboards and providing libraries of digital material tailored for school teaching, like the *Lokando SCHOOL Themenbank* [54].

The largest German museum of science and technology, the Deutsches Museum [18] in Munich, uses E-Chalk in a project where visitors are asked to record a description of their favorite experiment from the Chemistry exhibition, see Figure 8.1. To promote the use of audio in the recording, the visitor is engaged in a conversation about the experiment by a museum employee sitting vis-à-vis during the recording. Some configuration settings were introduced to the E-Chalk board for this experiment to further reduce the tool dialog options. However, the Deutsches Museum team uses the standard setup, as it was thought from their initial experiments that "everyone immediately understands

Figure 8.1: Left: English lesson with E-Chalk at a German school, the Wilma-Rudolph-Oberschule in Berlin. Center: A young visitor of the Chemistry department of the Deutsches Museum in Munich describing his favorite experiment with E-Chalk. Right: The artist Kiddy Cidny streaming a live art performance into the Web.

how to operate the software anyway", whether the visitor is a young child or an older person. The only feature reported not to be obvious to uninitiated users are the *drag handles*. On the other hand, once demonstrated, the feedback on the *drag handles* was always positive.

Pathologists at the *Klinik am Eichert* hospital in Göppingen, Germany, plan to adopt E-Chalk combined with a video-conferencing system for ad-hoc communication about diagnostic findings with physicians in other places.

The system was even used in an art event. The *Himmel5* art show [34] organized a performance streamed live into the Web, see Figure 8.1.

8.1.1 Hardware Setup in the Lecture Room

When using the E-Chalk software in classroom teaching, one needs a pen-based input device and a large display for the audience. Ideally, the display itself is the writing surface, increasing the similarity to the chalkboard usage. This can be realized by using digital whiteboards or rear-projection systems with pen tracking. The whiteboard systems are basically wide, perpendicular mounted digitizing tablets with a diagonal of up to 80 inches. The screen content is displayed by an LCD projector, see for example Figure 8.2. This front projection has the disadvantage that the lecturer may cast a shadow on the board, interfering with his or her writing on the board. Rear-projection systems do not know this problem and they are less susceptible to adverse light conditions, but they are also less portable than whiteboards and much more expensive.

For both systems, the display area is large enough for a seminar room of typical size, but not for a large auditorium. This can be solved by a second LCD projection at a bigger scale. The Technische Universität Berlin applies such a setup regularly, see Figure 8.2.

An alternative setup is to use a digitizer tablet or a Tablet PC as the input device and combine this with a projection for the audience. Digitizing tablets are comparatively cheap[1] and easy to transport. Using a model with an integrated display, the teacher does not have to turn away from the audience for writing. For a fixed installation, the tablet can also be integrated into a lectern, see Figure 8.3 for an example.

[1] Digitizing tablets without integrated displays are available for less than $50.

Figure 8.2: Left: E-Chalk running on a digital whiteboard with front projection (*Numonics IPM*). Right: Mathematics lecture at Technische Universität Berlin using the same digital whiteboard model and an additional projection for the audience.

Providing the writing surface this way can also be helpful in other scenarios. A handicapped professor of Arabic Linguistics was delighted to be able to give a chalkboard lecture while seated using a digitizer tablet for himself [12]. Before, the wheel-chair-bound professor always had to have a student or assistant to do the blackboard writing for him. Another example is a setup at a German high school, where the computer room is too cramped for the regular classroom setup. There is not enough room for a blackboard, and students' desks provide just enough space for the computer hardware, not leaving enough space for taking notes. The teacher uses E-Chalk with a small digitizer tablet and projects the board content onto the wall, see Figure 8.3. The E-Chalk PDF is printed out at the end of the class so that students have access to a written copy of the material covered in class.

For smaller seminars, one can use a setup with several digitizer tablets, enabling students to interact with the board contents from their own seats. In the case shown in Figure 8.4, the Geology lecturer uses a rear projector and the students use small digitizer tablets to work on geographical maps.

FU Data Wall

At Freie Universität Berlin, a rear-projected data wall was built to provide a spacious electronic board hardware [FKRT04], see Figure 8.4. The wall display is composed of four screens controlled by a single PC with a multi-head graphics card. The pen is a laser pointer, turned on by being pressed against the screen surface. The laser light is tracked by cameras; a webcam is positioned behind each display. The camera signals are fed into a second PC, which searches for the laser pointer's signal, computes a mouse position from it and sends the position to the display-handling computer. A receiving program acts as a mouse driver, setting the mouse position accordingly. For a detailed description see [Die03].

However, this solution only provides a kind of zero-button mouse. To add more features to the pen, the driver has been enhanced to handle additional signals sent via bluetooth, see [Reb04].

The extra space of the data wall are used with E-Chalk to show previously

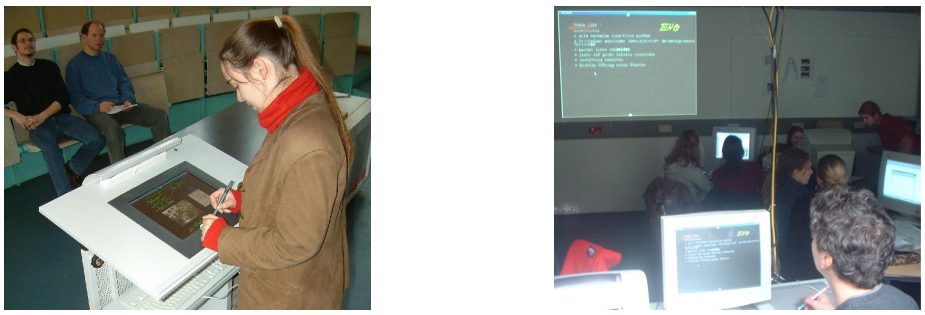

Figure 8.3: Left: Digitizer tablet with integrated LCD tablet (Wacom *Cintiq*) integrated into a lectern at the the Computer Science lecture hall at Freie Universität Berlin. Right: Digitizer tablet (Wacom *Graphire*) used at a German high school, the Erich-Hoepner-Oberschule in Berlin.

developed parts of the board lecture, giving the classroom audience more context information, see Figure 8.4. Only the rightmost quarter of the display is used by the lecturer for drawings. Allowing contents to be added to the other three screens would result in problems with replay on displays with regular resolution.

The three passive windows shown in addition to the default E-Chalk screen are realized as E-Chalk clients replaying the live stream. An Applet parameter[2] causes them to display the content shifted vertically by one to three screen heights. When the user scrolls the board, the E-Chalk live server sends the action to the three clients, and all offsets are adjusted accordingly. The setup with the three special board Applets is defined in a custom HTML template (see Section 3.7) for the live setup. An optional E-Chalk configuration entry specifies native commands to be executed directly before the recording session starts, used in this case to launch a browser opening the live HTML page and starting the three clients.

8.1.2 Uses for Remote Access

It is also possible to create a recording without an audience and to publish it solely for remote access, see for example Figure 8.5. This approach has been chosen by users to produce revision material of the subject, all well as extra content to be learned as a homework, and in at least one occasion to replace a class where a date collision occurred for the instructor.

The E-Chalk software can also be used for synchronous remote access to the lecture. Apart from experimental seminars shared between remote locations, there was also a regular lecture taught at Freie Universität Berlin from a remote location. The instructor was in one place, the audience in another. To extend the communication capabilities, E-Chalk was used in combination with a video-conferencing system. Voice and video image were transmitted two-way by video conferencing and at the same time the board content was sent to the audience by the E-Chalk server, see Figure 8.5. Board and lecturer's voice were recorded as an E-Chalk lecture.

[2] See `yoffset` parameter described in Section 7.2.5.

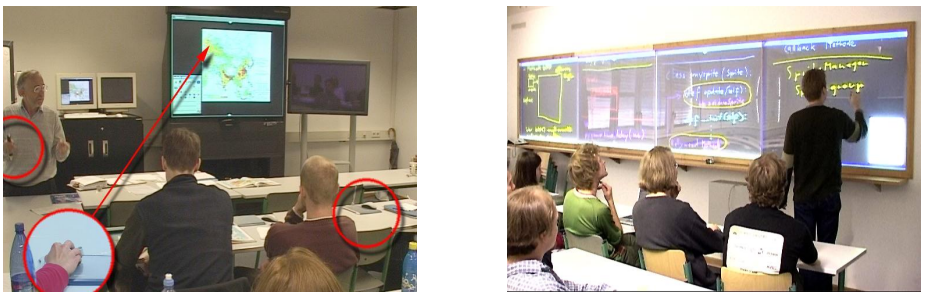

Figure 8.4: Left: Geology seminar at Freie Universität Berlin using a rear projector with laser-tracked pen (Hitachi *StarBoard R-70X*) and several tablets (Wacom *Graphires*). Right: The data wall constructed at the Computer Science department of Freie Universität Berlin.

Except for such special situations, however, the demand for live transmissions is marginal. Most students who do not visit the lecture prefer to view the recording at a later time, especially as the live transmission does not really give them an extra benefit. To add extra value to the live transmission, a communication tool like a chat line may be added to the HTML pages[3], perhaps even with a lecturing assistant joining the chat.

According to feedback from learners, the preferred use of E-Chalk recordings is exam preparation. The material is also used by learners who did never visit the recorded lecture itself. A student at Fachhochschule Trier, for example, used recordings of lectures on Neural Networks from Freie Universität Berlin to prepare for his final exam and afterwards contacted the E-Chalk team members, sending a bottle of wine to thank them. Also, at least one Berlin student was not able to visit this very Neural Networks lecture due to lectures collisions, but instead relied purely on the recordings, and successfully took an exam for the lecture. Not only university students use the materials. The E-Chalk team have also got reports from high-school students using the opportunity to take a look at university lectures with the help of E-Chalk.

8.1.3 Replay on Hand-held Devices

The replay of E-Chalk recordings is also possible on hand-held devices. Although a Java Runtime Environment is often not pre-installed, Java 1.1 can be set up on PDAs by installing the *Jeode* Java Virtual Machine for Microsoft Pocket PC from Esmertec [24]. This is sufficient to run the E-Chalk replay. The same holds true for those mobile phones running Windows CE Pocket PC, see Figure 8.6. Other Java-capable mobiles, for example those that run Symbian OS, normally support only the Java 2 Micro Edition (J2ME). Running E-Chalk on such devices would require a reimplementation of the client as Java Midlet.

The main problem with running E-Chalk on a mobile or a pocket PC is the small display. Lectures recorded with a resolution used by standard PC displays will be hard to follow on a hand-held device, requiring the user to scroll a lot to the actual center of activity. For use with small screens, smart

[3]This can be easily done by editing the E-Chalk HTML templates, see Section 3.7.

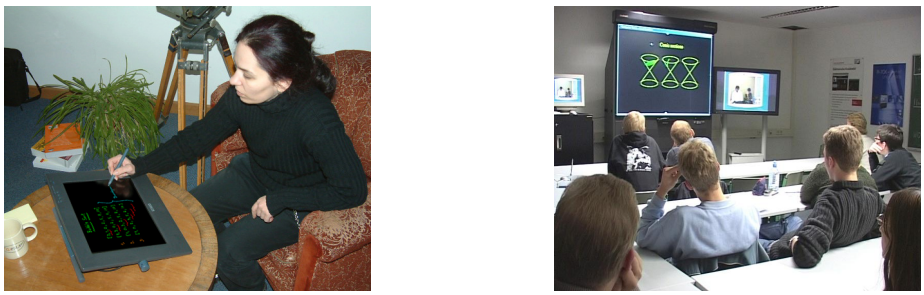

Figure 8.5: Left: Using a microphone and a digitizer tablet, lessons can be created at home. Right: A lecture on robotics transmitted from Stanford University to Freie Universität Berlin by combining E-Chalk with a video-conferencing solution.

Figure 8.6: The E-Chalk client running on a mobile phone.

display technologies still have to be added to the E-Chalk client. For example, the image could be scaled using a kind of fish-eye view and the board could automatically center the current area of changes.

8.2 Evaluations

Two field studies [Sch03, FKR+04b] have been conducted on university courses to evaluate the use of E-Chalk, its impact on teaching, and its acceptance under real-life conditions. These studies were arranged by media psychologists from Freie Universität (FU) Berlin and Technische Universität (TU) Berlin. The emphasis in the examinations lay on the explorative description of key questions, such as the acceptance of the software and possible effects on the students' motivation for studying. The evaluated courses were held at FU and TU Berlin. The results are summarized in the following sections.

lecture title	university	approx. class size	questionnaires start of term	questionnaires end of term	questionnaires sum
Neural Networks	FU	80	36	24	60
Introduction to Numerics	TU	40	18	0	18
Calculus II for Engineers	TU	300	117	0	117
Linear Algebra for Engineers	TU	300	94	0	94
Numerics for Engineers	TU	50	50	36	86
Introduction to Physics for Engineers	TU	300	113	107	220
sum		1070	428	167	595

Table 8.1: Questionnaires returned from lectures having been evaluated during the summer term of 2003.

8.3 Studies During Summer Term 2003

Methodology

The main source of data for the evaluation [Sch03] were questionnaires filled out during the lectures. See Table 8.1 for a detailed listing. The TU Berlin lectures were held in the context of an e-learning project named *Moses* [64]. As the students were also asked to take part in evaluations for Moses and for the regular teaching evaluation by the department, their load of questionnaires was quite high. To avoid irritations, it was decided to skip the survey at the end of the term for three of the lectures.

595 questionnaires were evaluated and 52 students were identified to have answered the questions twice, at the start and at the end of the term. Their responses were examined for changes of attitude.

The lectures at TU Berlin were held at the departments of Mathematics and Physics. In his *Introduction to Physics for Engineers*, the instructor used an LCD digitizer tablet for pen input, and the board image was shown to the audience using an LCD projector. In the other four TU lectures, a digital whiteboard with front projection was used together with a second projection for the audience. This setup, installed at TU Berlin in several lecture halls, is shown in Figure 8.2. Live transmission of the lecture was not provided, but the board recordings were made available for replay together with the PDF version of the board image. Audio was not recorded due to audio recording hardware not being installed in the lecture halls at that time.

The surveyed FU lecture was held at the Computer Science department. Here, E-Chalk was not used in classroom teaching. Instead, the lecturer used the system to record the content of lectures in advance. The recording of board and audio stream and the PDF transcript were made available for revision purposes. All lecture materials were put into a learning-management system[4], which gave some statistics on the student's access to the materials as an additional data source.

[4]The LMS used was Blackboard [4].

data source	observed group	notes
595 questionnaires	ca. 1100 students	start (April/May) and end (July) of summer term 2003
893 short questionnaires	ca. 900 students	coupled with exam, July 2003
6 interviews	6 instructors	July 2003
Web accesses to E-Chalk material	80 FU students	by log file analysis for April to July 2003

Table 8.2: Data gathered by the first evaluation on E-Chalk [Sch03].

All six lectures had an exam at the end of the term. To evaluate E-Chalk's influence on exam results, the participants were asked about how much preparation they had done for the exam. In addition to the surveys on the students' opinions, the six lecturers were interviewed by the evaluator and asked their opinions on, and experiences with, E-Chalk. An overview of the survey data gathered is given in Table 8.2.

Findings

In the TU Berlin courses, the printable PDF was preferred to replay of lectures by most students. The low popularity of the replay hardly came as a surprise, as no audio signal was recorded at TU Berlin. Students at FU Berlin used the PDF and the replay on an equivalent level.

According to the statements on the amount of remote use, the remote accesses intensified (in *Introduction to Numerics* and *Neural Networks*) or remained at a constant level (all other courses) during the term. This result is supported by access statistics from the *Neural Networks* lecture, see for example Figure 8.7. The rising intensity probably indicates students' preparation for upcoming exams.

However, no significant correlation between exam results and E-Chalk use could be found. In all user categories almost the same grade has been achieved, compare Figure 8.8. The report suggests further examination by forming two groups with the same external conditions differing only in the use of E-Chalk.

Adopting E-Chalk in teaching did reveal neither positive nor negative effects on the students' motivation to prepare for the lecture. The quality of the software was judged positively by the students. Didactic quality of the courses was perceived well compared to regular courses, see Figure 8.9.[5] Students welcomed the extra flexibility in learning, both for increased independence in time and in location.

There is a small tendency (below statistic significance), that students reduce the amount of note-taking compared to regular courses.

Lecturers' skills regarding software handling improved noticeably during the term (statistically highly significant, i. e. an error probability of less than 1 %). According to the interviews, time needed by lecturers to get fully accustomed,

[5]The original German names of didactic categories in the questionnaire were *Anschaulichkeit*, *Verständlichkeit*, *Nachhaltigkeit*, *Konzentration*, *Wissenszuwachs*, *Interaktion*, and *generell*.

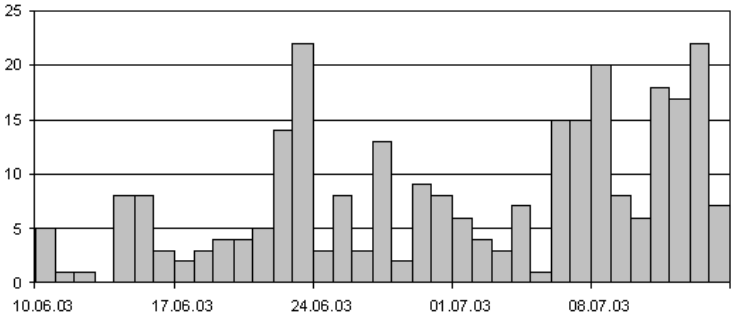

Figure 8.7: Number of E-Chalk replay accesses in the evaluated FU Berlin course from June, 10th, until the day of the exam on July, 14th.

ranged between one and four lectures. [Sch03] judges this as an indication for the easy handling of the software.

The questionnaires included requests for commentaries, for advantages of E-Chalk, for disadvantages of the system, and for suggested improvements.

The most frequently-mentioned advantage was a clear, readable board image (mentioned 189 times), followed by comments on remote access (73 times), revision material (62 times), enhanced visualization facilities with Applets and images (36 times), and the elimination of need for copying the board content (26 times). A few students also noted that the lecture was easier to follow with the system (15 times).

The most common complaint was concerning the stability of the system (61 times). This impression, however, is explained by a hardware problem in the PC running E-Chalk in the main TU lecture hall. The PC, used exclusively for E-Chalk lectures, had a faulty memory chip, frequently causing the OS or the E-Chalk applications to crash. Unfortunately, the cause of this problem was not identified until late in the term. However, the several damaged E-Chalk recordings led to the development of the lecture repair tool described in Section 6.6.

Also common were complaints about the visual quality of the board image (58 times, mainly remarks on resolution) and the relative size of the board (51 times). A likely cause for these shortcomings is the displayed resolution being too low, forcing the instructor to write bigger letters for improved readability. While the digitizer whiteboard hardware is theoretically able to recognize the pen location way beyond the accuracy of the human hand[6], the resolution is limited by the screen resolution of the projector and the controlling computer's graphics card. In fact, it is not even desirable to use very high resolution here, as this would make the replay on computers with lower resolutions very inconvenient, unless extra mechanisms for small-screen rendering are added to the client, as discussed in the context of small screens in Section 8.1.3.

[6]The *Numonics IPM* whiteboard used in the lectures at TU locates the pen by electromagnetic induction with wires embedded in the board at a density of 300 per inch. In practice, the accuracy is not limited by the hardware but by the calibration of the mapping between physical location and projection image, and estimation errors introduced by the driver software doing this mapping.

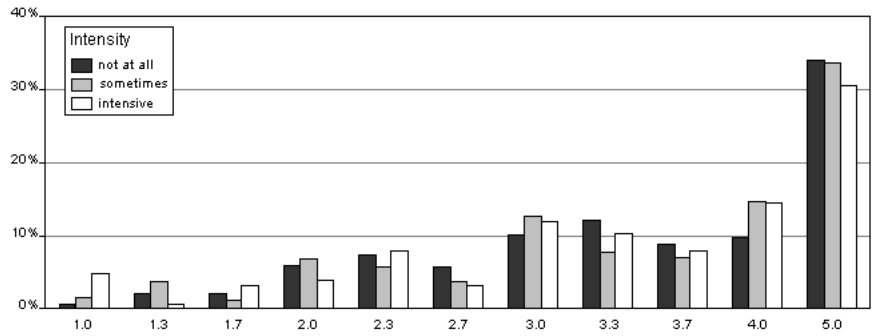

Figure 8.8: Exam results in correlation with the usage of E-Chalk materials, where 1.0 is the best grade.

Another frequent complaint was the bad handwriting of the instructor (40 times) and the missing audio in the TU Berlin recordings (20 times). Low handwriting quality is likely to be due to the low resolution mentioned above.

Suggestions for improvements included, among others, the application of integrated handwriting recognition, an additional projection of the former board content (similar to the approach taken with the FU data wall, see Section 8.1.1), a pointer or marker tool (discussed as a future addition in Section 9), and displaying the current time. The latter feature was added to the system shortly after the study by showing the recorded time duration or the local time in the title of the board frame. Which of the two options is used can be configured in the setup.

Other requests concerned distribution of lecture recordings on CD-ROM and archives for E-Chalk material to make recordings from former terms available.

The lecturers interviews showed that most board features were used rarely, except for the basic writing features and including of images. Instructors preferred the eraser to the undo function. However, switching between pen and eraser for minor corrections was cumbersome. In reaction to these findings, the possibility to toggle between eraser and drawing tool by the right mouse button (equivalent to the extra button on the pen of the Numonics whiteboard used in most TU lectures) was added.[7] All lecturers used a black board background. Their preferred writing color was green, as it offered a good contrast both to the black background on the board and to the white background of the PDF transcript. There were some complaints about several colors having bad contrast in the PDF due to the background color change and about the PDF page separation running through writing. This caused the introduction of the outline feature for the PDF contents (see Section 6.1.3) and a page-separation algorithm that considered the vertical distribution of the contents (described in Section 6.1).

Another suggestion for improvement was a preview function for images, realized as a thumbnail option for bookmarks.[8] Lecturers would have liked to

[7] This feature is active in the default setup, but can be deactivated, as some users have trouble when hitting the extra button by accident, especially for the smaller pens that come with digitizer tablets and Tablet PCs.

[8] For image file chooser dialogs, a preview function still has to be added.

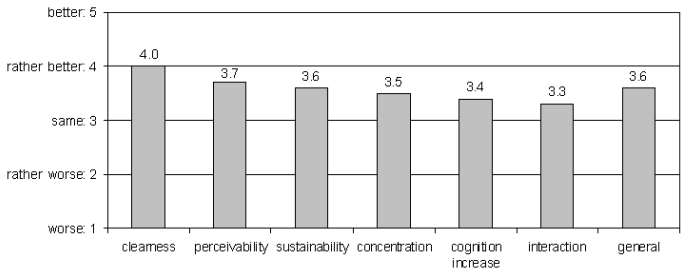

Figure 8.9: Average scores on aspects of didactic qualities of E-Chalk courses.

have personalized settings, which have now been implemented, see Section 3.1.2. A Mathematics lecturer requested integration with Maple, as his department worked with Maple instead of Mathematica. Again, this request has been implemented, see Section 4.6.2.

When questioned about advantages and disadvantages of the system, most of the instructors' answers were similar to the most frequent students' comments. In addition, they judged as being 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 missed the small pauses introduced in traditional chalk lectures by the action of wiping the board.

Additional disadvantages were observed in the hardware setup. At TU Berlin, both mobile and fixed digital whiteboard installations were tested. These tests showed mobility not to be desirable. Even slight movements, possibly unintentional, required the whiteboard to be recalibrated. Even with fixed whiteboards, the lecturers faced the problem that they needed some time before each lecture for calibration, because the whiteboard projector was not fixed. Another problem with front projection at TU was that instructors were sometimes looking into the projector light when turning to the audience. While these problems could for example have been eliminated by a ceiling-mounted projector, the layout of the TU lecture halls did not allow for this solution. Some lecturers reported trouble with their own shadow hiding the projection while they were working on the board. The problem was increased by the low distance of the projector to the board, resulting in a big shadow.

As a consequence of these problems, most TU courses switched to the setup with an LCD tablet as pen input, see Section 8.4.

Summary

The initial evaluation confirmed E-Chalk to be a beneficial and usable system for teaching. A number of minor improvements have been added in response to the evaluation feedback. Fundamental assumptions on the system's conception were confirmed by the main conclusions [Sch03, FKST04] of the study:

- Overhead work to use the software for lecturing is limited to the start of the term for a setup.
- The lecturer can easily integrate material from previous terms.

lecture	term without E-Chalk	questionnaires without E-Chalk	questionnaires with E-Chalk	sum
linear algebra for engineers	2001/02	170	222	392
computer-oriented mathematics	2001/02	90	66	156
numerics I for engineers	2002/03	39	22	61
differential equations for engineers	2002/03	132	56	188
sum		431	366	797

Table 8.3: Courses and number of returned questionnaires evaluated in the study comparing E-Chalk courses during the winter term of 2003/04 with non-E-Chalk courses of previous winter terms.

- Traditional chalkboard skills directly translate into skills for good E-Chalk lectures.
- In practice, the use of plain drawings and writing predominates. Advanced features like the integrated computer algebra system or calling CGI scripts are only rarely used.
- If audio were recorded with the lecture, students made use of both replay and PDF printouts on an equal level.

8.4 Studies During Winter Term 2003/04

Three more evaluation studies were performed during winter term of 2003/04, covering E-Chalk courses at Freie Universität Berlin and Technische Universität Berlin. More results of these studies can be found in [FKR+04b] and [FKR+04a].

8.4.1 Comparative Studies

Two studies compared E-Chalk courses to traditional ones. In the first of these studies, there were exercise courses on the same subject ("design and analysis of algorithms") and held in the same term at the FU Berlin Computer Science department, but differing in the teaching technique. One course was taught with E-Chalk, the other with a traditional blackboard. The E-Chalk recordings included audio and were made available on the Web for remote access.

The students were given the standardized VBVOR [Die98] questionnaire to get their opinions on the course's quality. In each courses, 20 questionnaires were returned.

The results [FKR+04b] of this study yield favorable findings on E-Chalk. The statement "*In my opinion, the topic of the course is very expedient in the context of my study*" received a higher agreement in the E-Chalk course and the statement "*Too much content was covered in the course*" received less agreement with E-Chalk. Asked how often they attended the classes, there was also a tendency to reduced presence in the E-Chalk classes. This result, which might be judged favorably or not, is very likely a consequence of the supplied

course type	course title	instructor	university	questionnaires
lecture	linear algebra	A	TU	127
lecture	linear algebra	B	TU	37
lecture	computer-oriented mathematics	C	TU	65
exercise	design & analysis of algorithms	D	FU	11
exercise	design & analysis of algorithms	E	FU	16
exercise	design & analysis of algorithms	F	FU	9
seminar	cartography	G	FU	10
seminar	cartography	G	FU	15
seminar	cartography	G	FU	13
sum				303

Table 8.4: Courses and number of returned questionnaires for the quantitative winter term 2003/04 study.

E-Chalk materials making it easier to revise material of a class one has missed.[9]

The second comparative study is based on the data of the evaluations performed every term at the department of Mathematics at Technische Universität Berlin for all of its courses. The study compared earlier data on four courses taught without E-Chalk with data of the same subject taught by the same instructors but with E-Chalk in the winter term of 2003/04. For the classes without E-Chalk, data returned by 366 students were gathered, for the E-Chalk lectures, 431 questionnaires were filled out. See Table 8.3 for a detailed breakdown of the numbers. The main statistically significant results on E-Chalk lectures are [FKR$^+$04b]:

- Students judged E-Chalk classes to contain more repetition of relevant subject matter. The distribution of grades shifted away from *too little repetition* towards *too much repetition*.

- The instructor receives worse rating for his or her speech intelligibility. Note that this concerns the speech in class as no audio was recorded. Maybe the lecturers were too much involved in handling the E-Chalk technology, distracted from turning to the students and speaking out clearly.

- Students in E-Chalk lectures consider instructors' board writing to be less well structured. This is most likely a consequence of the real screen being smaller than on a traditional board. For a discussion of this problem, see discussion of commentaries in the main findings part of Section 8.4.2.

- A lower attendance rate at classes is highly significant (with an error probability of less than 1 %).

[9]The original German statements were "*Das Thema dieser Veranstaltung halte ich im Rahmen meines Studiums für sehr sinnvoll*" and "*In der Veranstaltung wurde zu viel Stoff behandelt*". The question on the number of class attendances was "*An wie vielen Sitzungen der Veranstaltung haben Sie nicht teilgenommen?*"

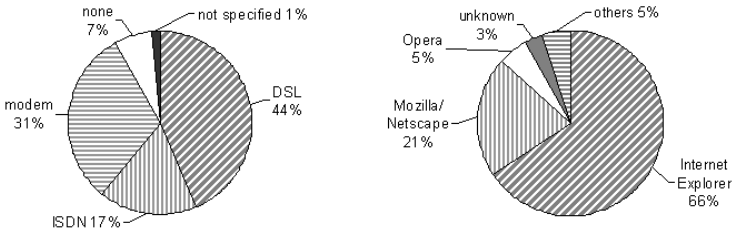

Figure 8.10: Results on the technical equipment of students questioned in the winter term of 2003/04 qualitative study. Left: Internet-access types. Right: preferred Web browsers.

8.4.2 Qualitative Study on E-Chalk Courses

The evaluation target was to further explore how and when extra offers by E-Chalk were really used by students and to get their opinions on the system. Questions were posed about the computer equipment of users, their usage pattern of E-Chalk materials, and the quality of the software, both in general and in comparison with other teaching technologies. Only the main findings of the evaluation are presented here. A more detailed listing can be found in [FKR+04b].

Evaluated Courses

Nine courses using E-Chalk were evaluated at Freie Universität Berlin and Technische Universität Berlin in the winter term of 2003/04. A total of 303 questionnaires were returned by students. Table 8.4 shows details on the type of the courses and the number of returned questionnaires.

At TU, the lectures were given in the auditorium shown in Figure 8.2. The lecturer wrote on a digitizer tablet with built-in LCD screen. The screen was projected for the audience to read. As the auditorium was still not set up for audio recording in that term, only board stream recording and PDF script generation were provided on the Web. The seminars and tutorial courses at FU were held in a seminar room with a rear projector, see Figure 8.4. The exercise courses recorded board and audio and made the replay available for Web access together with the PDF transcripts. For the three cartography seminars, E-Chalk was exclusively used for classroom teaching. No recordings were made available for distance teaching. In class, a number of digitizer tables at the students' desks were used to allow the students to work on the screen from their seats. The instructor used this to promote interactivity in his seminar. Without any E-Chalk materials being published for these seminars, all questions on remote usage were omitted in their questionnaires.

None of the nine evaluated courses offered live transmission of the class.

Main Findings

About 44 % of the students reported using a high-speed Internet access. About a third still used a modem connection, see Figure 8.10. This is a good indicator of the importance of having only low-bandwidth requirements imposed by

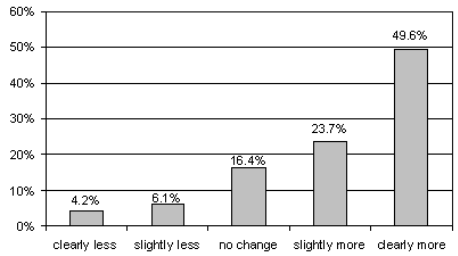

Figure 8.11: Note-taking behavior reported by students for E-Chalk classes in comparison with regular classes.

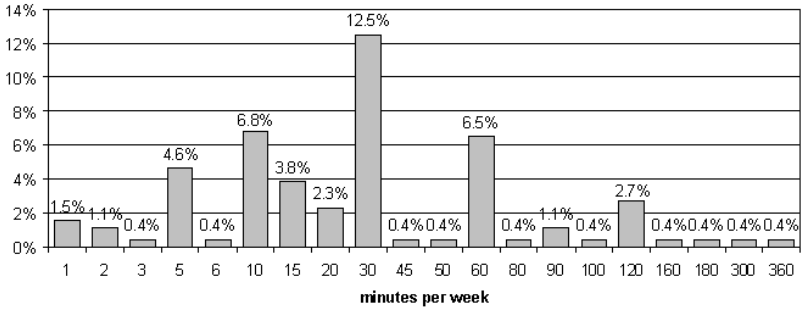

Figure 8.12: Time reported to be spent doing revision with E-Chalk materials in courses where recordings were published on the Web. The 53.2 % bar for zero minutes per week has been omitted.

E-Chalk. Note that these numbers derive from questioning mainly students of Computer Science, Mathematics, and Engineering subjects. In faculties with the average students being less computer inclined, high-bandwidth connections can be assumed to be even less common.

A Windows operating system was used by the overall majority (89 %), followed by Linux and Mac OS X. The dominant Web browser was the MS Internet Explorer (66 %), with Mozilla/Netscape ranking second (21 %).[10] No correlation exists between E-Chalk usage and bandwidth, thus it can be assumed that E-Chalk is equally usable with any type of connection.[11]

Asking students about the amount of note-taking in E-Chalk classes compared to regular classes yielded about 60 % of students taking at least as many notes in E-Chalk classes as in conventional classes. See Figure 8.11 for the distribution of answers. Note that this tendency seems to be contrary to that of the summer-term evaluation.

[10]Note that these figures were collected before mid-2004, when media reported a notable loss in browser market share of the – still dominant – Internet Explorer. See for example [33].

[11]The same holds true for comparing Internet Explorer users with Mozilla/Netscape users. For other browsers, the numbers of mentions were too low to get any statistically significant results. As to the operating system, the numbers for non-Windows systems were also too low for comparison purposes.

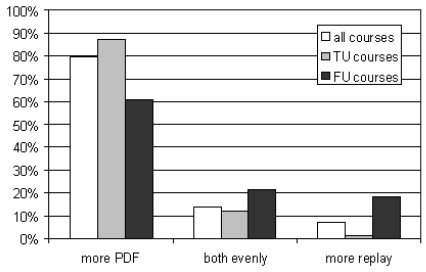

Figure 8.13: PDF was preferred over replay, especially at TU, where no audio was recorded.

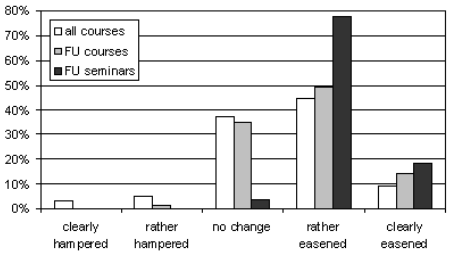

Figure 8.14: Students' opinions on the system's impact on the organization of their study.

About half of the students (46.8 %) reported using the E-Chalk 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 E-Chalk for revision, the average was 40 minutes, the median 30 minutes. However, these figures should not be taken to literally, as they display a high degree of variance. See Figure 8.12 for details.

When asked for the type of E-Chalk material mainly used for revision, most students preferred the PDF over the replay, especially TU students, see Figure 8.13. Just as in the evaluation of the previous term, replay has been expected beforehand to be unpopular among TU students, because the recordings did not include audio.

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. The most favorable results were observed for FU seminars, where the system was used for interactive teaching, see Figure 8.14.

These answers were investigated as to a correlation with the preferred use of lecture materials for revision. Those students who did not use any E-Chalk material at all noticed no significant impact. The number of replay-preferring users was too low to yield a significant correlation, but PDF users and learners using both types of material expressed a clearly positive judgment, see Figure 8.15.

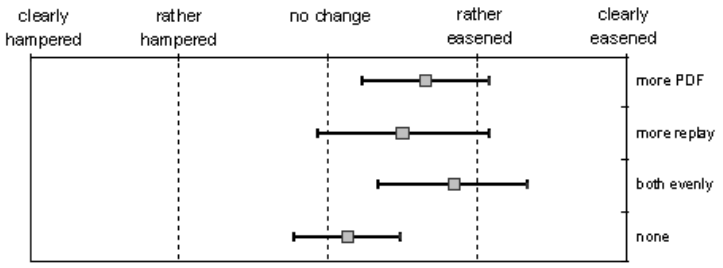

Figure 8.15: Average values and their 95 % confidence intervals for opinions on simplification, evaluated separately by preferred type of revision material.

The evaluation also examined the students' opinions on the quality of the system. The answers on 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 talk was judged positively in classroom teaching[12], and got worse ratings for the replay, see Figure 8.16. This result was a major motivation to enhance the audio recording quality in E-Chalk by the approaches described in Section 5.2.

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 E-Chalk in the evaluated course received above-average marks from 73 % of all students. See Figure 8.17 for a detailed breakdown of the proportions.

To compare E-Chalk with other teaching techniques, the students were asked to judge, in a fictional comparison, between E-Chalk-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. E-Chalk was favored above all these three teaching media, with PowerPoint coming closest and overhead slides ranging last, see Figure 8.18.

Finally, the students were asked to give commentaries on three categories, on the advantages of the E-Chalk system, on its disadvantages, and on suggestions for improvements. The most often repeated advantages include praising remarks on the appearance and organization of the board content (79 times), remarks on revision opportunities (71 times), that is is no longer necessary to copy the board content (33 times), the improved visualization by using images and/or Applets (28 times), the possibility of remote access (22 times), and the learners having more time and concentration to follow the lecture (20 times). Further remarks made at least five times were that it is no longer necessary to wipe the board (19 times) and an improved adaption of the instructors' speed to the audience (7 times). Among the facts mentioned more than once users remarked that one can scroll back to previously written content, the spontaneous and interactive development of the classes, and an increased motivation of the learners.

[12]Note that teaching with E-Chalk might have an impact on teachers' speech intelligibility. For example, using a microphone might change the lecturer's speaking style. See also the results on speech intelligibility from the second comparative study in Section 8.4.1, where detrimental effects were observed.

Figure 8.16: Opinions on visual (left) and acoustic (right) quality, both in classroom and replay. Replay quality was only evaluated in those courses where the associated streams were published on the Web.

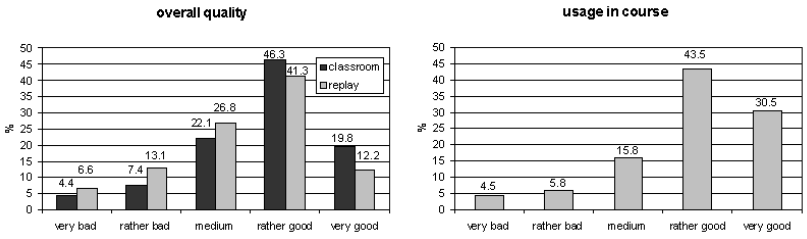

Figure 8.17: Left: Answers on the overall quality of the system. Right: Ratings for using E-Chalk in the evaluated course.

As to the disadvantages, a low readability of the instructors' handwriting was by far the most common complaint made (121 times), followed by criticizing the visual qualities of the board image (24 times), for example demanding a higher screen resolution, problems already discussed in the findings part of Section 8.3. However, the complaints about handwriting readability increased a lot. Presumably this is caused by the change of pen-input hardware at Technische Universität Berlin. While the accuracy of the LCD tablets seems to be high enough for the resolution, it is supposed harder to produce clear handwriting on a small screen than on the whiteboard, where bigger movements are used. Some students remarked the board drawings to be not clearly laid out (15 times). This is likely to be caused by both the resolution problem and the smaller size of the digitizers and rear projectors compared to a traditional chalkboard. The problem of visible board space itself was also criticized (9 times). This is a problem not to be solved easily with off-the-shelf display technology, as the aspect ratio of the projection is determined by the computer-screen ratio, and the height of the board is limited by the instructor's ability to reach the upper part of the board. With special hardware setups, one can provide more display space in the classroom, as shown in Section 8.1.1. For remote access by standard PCs, this introduces the need of mechanisms to fit more board content onto a small screen, compare Section 8.1.3.

Other remarks given at least five times are no recording of audio (at TU, mentioned 11 times), and the lecturing speed being slowed down (5 times).

As to improvement suggestions, a demand for a higher screen resolution

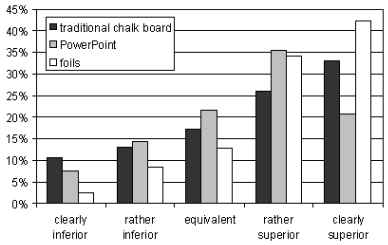

Figure 8.18: Students' opinions on teaching with E-Chalk compared to using other types of lecturing tools: to traditional chalkboards, to PowerPoint, and to overhead slides.

appeared again (14 times). Training for instructors on using E-Chalk was requested (9 times), and a few features have already been considered for future work[13], like a marker tool (requested 2 times), a feature for using backgrounds like lined and grid paper (4 times), and transmission of the cursor (4 times). Handwriting recognition, which is already integrated for some purposes[14], and is planned to completely replace the need of the keyboard for all E-Chalk controls in the future, was the most common request (21 times).

Almost all additional commentaries were requests for features which were already fully supported, but not used in the evaluated lecture, like changing colors used (11 times, for example switching to a dark gray background), demands that instructors use or increase their usage of images, animations, and Applets (8 times), recording of audio (4 times), adding a scrollbar to the board (3 times), download possibilities of the recording (requested 2 times, was available in all TU lectures, and in some of the FU courses), a bigger drag point (2 times, already adjustable in the setup), and recording of video (1 time).

[13]See Chapter 9.

[14]Handwriting recognition is only integrated in the system so far for calculations, see Section 4.8, and in experimental usage for indexing purposes, see Section 6.8.