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The Interactive Lecture: A new Teaching Paradigm based on Ubiquitous Computing

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Abstract— **In this paper we present a new teaching paradigm based on ubiquitous computing, which we call the Interactive Lecture. It specifically supports situations where the interactivity between students and lecturer is usually limited, such as lectures with a large number of students, or teleteaching scenarios. In an Interactive Lecture each student is equipped with a handheld computer. These computers connect to the computer of the lecturer via wireless communication. Interactivity between students and lecturer is then increased by a number of services. Examples for these services are: online-feedback which enables students to give immediate feedback about the lecture (e.g., about its speed and difficulty), or online-quizzes were all students participate in solving problems described by the lecturer. We have developed a first prototype of the software and performed a thorough evaluation during a graduate course. The results of this evaluation indicate that interactivity was increased significantly and that the students were very enthusiastic about participating in Interactive Lectures in the future.**

Index Terms— **Ubiquitous Computing, Handheld Computers, Education, Interactive Lecture.**

I. Introduction

Lectures in universities have profited from many technical advances over the last few years. The common blackboards were replaced by overhead projectors which again were substituted by video projectors and electronic whiteboards. Most lecture halls nowadays are equipped with computers as well as video and audio systems, allowing the integration of every possible type of media into the lecture.

However, the basic paradigm has remained largely unchanged throughout this time: the lecturer gives presentations, possibly using several different media to illustrate the topics of the lecture. For large classes in the order of more than 50 students, where spontaneous interaction is no longer possible, this leads to unidirectional communication and a lack of interactivity between the students and the lecturer.

Lecturers often attempt to overcome this problem by asking questions to trigger feedback on how well the students have understood the presented material, as well as provoke them to actively participate [Bli00]. For large audiences this is very problematic since only a small fraction of the students is able to interact with the lecturer in this way. The overwhelming majority will not profit from this form of interactivity and remain inactive.

A second, very natural, form of interactivity are questions asked spontaneously by the students. In large lectures this if often difficult. First of all, not all students are able to ask questions because of time constraints. Second, many students do not dare to ask questions in front of a large audience. Finally, if questions are taken only at certain times, the questions are out of context when finally asked. All three problems cause students not to interact at all.

Another problem arises if the lecturer wants to get feedback on how the lecture is accepted by the students and what he or she can do to improve the lecture. In lectures with a small audience the teacher can typically deduce this information from social cues, e.g., the students look bored or are inattentive. For large audiences this information is usually gathered by passing out feedback questionnaires to the students at the end of a lecture period. Unfortunately this approach is rather coarse-grained and does not allow the assessment of individual elements contained in a lecture. Furthermore it is not possible for the lecturer to quickly react to problems.

These issues have gained even more importance over the last few years by the rapid spreading of synchronous distance education. In an environment where a lecturer has to pay attention not only to a local audience but also to remote students, all of the problems mentioned above increase dramatically.

In this paper we present an approach to improve interactivity in lectures by equipping the students with small electronic devices (handheld computers) [RP02]. These devices communicate with the computer of the lecturer and thus allow to exchange information with the lecturer at any time, without disturbing the lecture. The type of information exchanged can be arbitrarily complex, ranging from a simple "virtual hand raising" over detailed feedback to quizzes that may even be counted towards the grades of the students. To avoid cost-intensive modifications of the lecture hall, the handheld PCs and the server are connected by a wireless LAN.

With our technology we aim to create a new form of multimedia-enhanced teaching: the Interactive Lecture. We have designed and implemented a prototype and performed a thorough evaluation of this concept during a regular lecture. The results of this evaluation suggest that the Interactive Lecture indeed increases the overall learning success as well as the motivation of the students.

Although our main intention is to improve lectures in universities and high schools, this approach may also be investigated for application in other mass events like press conferences, presentations or shareholders' meetings.

The remainder of this paper is structured as follows: in Chapter Two several related projects are presented that investigate the utilization of electronic devices in collaborative work and education. In Chapter Three, the Interactive Lecture is introduced and explained in detail. In Chapter Four, results of an evaluation which took place in January 2002 are presented. The paper ends with a conclusion and an outlook in Chapter Five.

II. Related Work

Many projects today are dedicated to *Ubiquitous Computing*, i.e., the integration of tiny computers in everyday life. Especially the involvement of small electronic devices for the collaboration in teams or in education receives is related to our work [RP02], [AAB+98], [AAF+96]. Some major projects are outlined below.

A. The Pebbles Project

The term *Pebbles* is an abbreviation for *PDAs for Entry of Both Bytes and Locations from External Sources.* In this context the term "bytes" stands for letters/numbers and "locations" for mouse positions. The intention of this project at Carnegie Mellon University is to allow multiple persons to use one central computer with their PDAs [MSG98]. This is done by remotely controlling the mouse pointer and the keyboard of that computer. An application was developed (the "Remote Commander") which controls the connections between several PDAs and the computer and solves some key problems like scaling (small display size on the PDA vs. big screen size on the computer) and floor control. The advantage in using this system is that during meetings all participants can use the electronic whiteboard (or the computer connected to a video projector) in turn without having to switch places.

While Pebbles can be helpful to support teamwork between students, it does not target the problem of a lack of interactivity between students and the lecturer.

B. SharedNotes System

The SharedNotes System was developed at the University of Calgary and deals with the utilization of handheld computers in collaboration and teamwork [GBL99]. Each participant is able to note ideas and items anytime and anywhere on his/her PDA. During the meeting, these items may then be published to other participants both by displaying them using a video projector or electronic whiteboard and by sending them to other PDAs for future use. Furthermore any annotations or changes to the discussed items are stored on the handheld devices, too, so there is no need to take other personal notes. Unlike other projects, the SharedNotes System tries to establish the handheld computer as an adequate working device, not only as a tool or terminal.

SharedNotes focuses on gathering notes and ideas anytime in order to then discuss and exchange these items later in a meeting. Thus it may be suitable for seminars or other collaborate work, but it is not possible to use this system to enhance interactivity in lectures since it implies a great deal of existing interaction.

C. A Multiple Device Approach for Supporting Whiteboard-based Interactions

This approach tries to solve common problems that occur when several people try to access a single electronic whiteboard simultaneously [Rek98], [PMMH93]. For this purpose handheld computers serve as input assistance just like a color skid for a painter. A new form of HCI technique was introduced, *Pick-and-Drop* [Rek97], where the user selects several parameters on the PDA like line width, color and shape with his pen and then uses the same pen to draw on the whiteboard using these parameters. The user may even "pick-up" media data from his PDA and then "drop" it onto the whiteboard. Although all information (parameters, media, slides, etc.) is transferred directly between the PDA and the whiteboard, it seems to the user that the functionality is inside the pen.

Similar to Pebbles and SharedNotes, this projects aims at enhancing collaborative work in small teams with not more than 20 participants. Thus it is not directly applicable to mass lectures which we are targeting. Several key elements of these approaches, though, could be integrated into an Interactive Lecture.

D. NotePals

NotePals was developed at the University of California in cooperation with the FX Palo Alto Laboratory (Xerox) [DLC+99], [DLB+98]. Since most participants of seminars, lectures, conferences or presentations write down personal notes, the idea of NotePals is to collect these notes and publish them on a web site to help the other participants. Similar to SharedNotes System a pool of knowledge comes into existence which covers far more information than the private notes of a single participant. The interface to be used is an application running on handheld computers on which the participant can compose his notes simply by writing on the display. The handwritten notes are then transferred to a server and processed by some OCR software. The notes, as graphic files, are then published along with the fragments of recognized text to enable keyword searching.

NotePals is an excellent example for the productive application of ubiquitous computing in the educational environment. By replacing traditional paper notebooks with PDAs important knowledge pools can easily be created for everyone's advantage. On the other hand this approach does not improve interactivity *during* the lecture.

E. Classtalk

This is an early approach to enhance interactivity in lectures [DGL+96]. During a lecture three or more times a problem (in form of a multiple-choice question) is displayed by the teacher, and the students have to solve it in collaborate work. The answer is then submitted over the infrared port of a TI pocket calculator (or over a special remote control-like device as used in later developments). All results are collected and immediately summarized by a central server and then displayed as a bar graph. In this way the lecturer is able to get information about how well the students have understood certain parts of the lecture, and to discuss the results immediately to further improve the learning success of the students.

While being a first attempt to increase interactivity, Classtalk covers only one possibility of classroom interaction (problem solving/quiz). It does not provide an integrated solution to increase interactivity. The devices and communication technology used by Classtalk do not allow the deployment in large lectures and limit the use of the system to infrequent occasions. In contrast we aim to develop an integrated solution, which is continuously used during a lecture.

III. The Interactive Lecture

The main goal of the Interactive Lecture is to create a new channel of communication between teacher and students. This channel is intended to allow new forms of interaction, which we call *interactive services*. For example, one service could be the ability of students to ask questions anytime without disturbing the general flow of the lecture. Another service could allow them to continuously provide feedback about certain aspects of the lecture, such as speed and difficulty. The lecturer, on the other hand, is able to distribute additional information to the students or to provide them with short exercises by means of appropriate services.

In an Interactive Lecture all students are equipped with handheld computers like PocketPCs or Palm PDAs. These devices are easy to be carried along and they do not obstruct regular classroom communication, as laptops or desktops would do. The students' devices are connected to a central server by wireless communication such as Bluetooth or WaveLAN (IEEE 802.11). Some handheld computers are already equipped with wireless networking facilities (mostly Bluetooth), others can be extended with common PC Cards without much effort. In this way it is possible to easily equip a complete lecture room without any construction work: a well-equipped notebook computer and one or two mobile access points are sufficient as infrastructure if the students bring along the mobile devices (either their own PDAs or equipment lent to them by the university).

A. System Architecture

Our software system to run the Interactive Lecture is designed as a classical client/server-application. As the central part of the architecture, the server provides the fundamental functionality: connection management, user management and service management. *Connection management* establishes connections to the clients upon request, processes incoming and outgoing data and monitors the registered connections for broken links. *User management* identifies individual users via password and stores personal information for internal and external use. *Service management* dynamically loads a requested number of plug-in service modules, informs clients about the availability of certain services and controls the data flow between the services, within the server structure itself and between clients.

The services provide the actual functionality that is visible to the users when they start their clients and connect to the server. Services are built as independent modules that must be loaded by the server at start-up time. They can be divided into two categories: services to be used before and after the lecture, which are mainly asynchronous, and services that are used during the lecture. The former are pretty obvious: messaging services to send small texts or graphics to other participants, chat and forum services to discuss certain items, and user management services to maintain user-specific information.

The client for the lecturer runs on a machine connected to the server via a traditional wired network. This client is specifically designed to match the higher functionality that is needed to operate the Interactive Lecture, e.g., activating quiz rounds or answering questions asked by students. All other clients use the wireless LAN to connect to the server. They are designed as a single homogeneous tool that is able to operate all services that are available in a particular setting.

Special care was taken to allow scenarios with more than one server. This is desirable in distance education scenarios, where more than one lecture room is included in a lecture. In order to support authentication of the students each site in such a scenario may prefer to operate its own server. To support this setting an external interface program can be used to connect two servers, making sure that at any time both servers have access to all data and all users while they still operate independently. Since the server allows more than one interface connection every imaginable server network topology is possible.

This interface technique can also be used to connect a server to an external application. For example, we have conducted first experiments to attach a shared whiteboard system to the server in order to provide a unified user interface for both systems.

The overall system architecture is shown in Figure 1.

B. Services

This section gives a short overview over the most important synchronous services that are used in the Interactive Lecture.

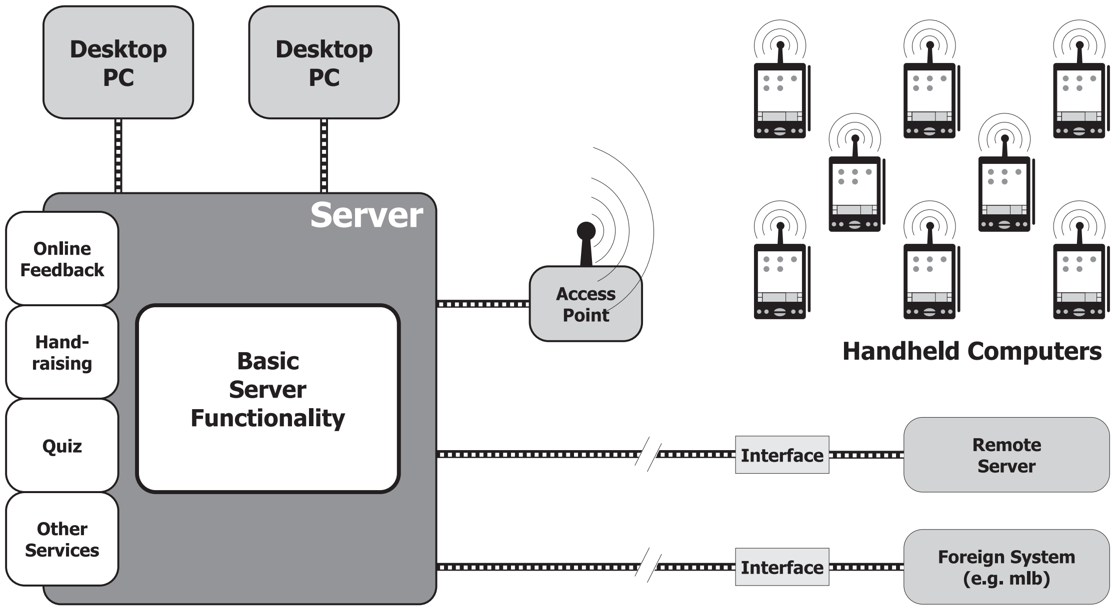


Fig. 1. Architecture of the Interactive Lecture software

Feedback This service enables the students to provide feedback to the lecturer at anytime. The lecturer is continuously informed about this feedback by means of bar graphs. To use this service, the lecturer sets up several categories; typical categories are speed and difficulty of the lecture. For distance education, additional categories are useful, such as video/audio quality of the transmission. Feedback categories are defined by a short description, the granularity and a characterization of the lowest and the highest value (e.g., "too slow" or "too fast"). Students may then express their opinion about the category by selecting a number between those values.

Call-In The Call-In service improves upon hand raising tools, which are already implemented in many videoconferencing applications. In addition to virtually raising his/her hand, the student may enter a question or remark directly into the mobile device and send it to the lecturer. The lecturer can use this additional information to choose an appropriate time for answering the question. Also, this feature can be used to create an archive of interesting questions and possibly answers. Of course this service also supports simple "virtual hand raising" as needed for very large lectures or in teleteaching environments.

Quiz A quiz is a task that is prepared by the lecturer before the lecture starts. At the appropriate time during the lecture the lecturer transmits the quiz to the handheld devices of the students, who will then enter their answers. The results are automatically graded, statistically accumulated and displayed. The quiz service supports the teacher to prepare the quizzes, to activate them during a lecture and to analyze the results during and after the lecture. Since we regard this to be the service with the largest potential to increase interaction between lecturer and students we describe it in detail in the next section.

C. Quiz service

Quizzes may be used for a wide range of applications, such as:

- short questions delivered to the students during the lecture to increase attention and to help them to better memorize the lecture,
- questions that help the lecturer to identify gaps in the students' knowledge,
- "live" exams with more challenging questions. The results will be taken into account for grading.

In all cases, the quizzes are prepared before the lecture takes place. A quiz consists of the question itself, definitions for the automatic analysis of the answers, media elements (typically pictures) and a grading value, i.e., the highest possible amount of credits to be gained when answering the entire quiz correctly. Anytime during the lecture, the teacher may then activate a quiz. Each student connected to the server when a quiz becomes activated receives the questions and is counted in the result statistics (even if he/she does not answer). The lecturer can monitor how many students have already answered and deactivate the quiz manually at an appropriate time (the question will disappear from the student's display, and no more answers will be accepted). Alternatively a timer can be set that automatically terminates a quiz round after a certain amount of time.

The results can be accessed immediately after the quiz has been deactivated. A window appears on the teacher's display showing the question together with the correct answer and an appropriate graph giving an overview over the answers received (Figure 2). This window can be shown to the students if the lecturer intends to discuss the results.

Fig. 2. The results of a quiz (from a course on multimedia technology)

Of course, only types of questions can be used that can be analyzed by the computer automatically based on provided reference values. E.g., exercises, where the students have to write an essay about a certain topic are nearly impossible to automatically analyze and rate without human influence. But there still is a broad range of possible quiz types, including:

- *Multiple Choice quiz with one correct answer*: this is perhaps the most obvious type of question for automatic analysis. Three or more possible answers are provided, with only one of them being correct (Figure 3). If the student picks a wrong answer or does not answer at all, he gains zero points, otherwise he gains as many points as the question is worth. The results are shown as a simple bar graph.
- A *Multiple Choice quiz with a variable number of correct answers* is very similar, but may have a variable number of correct answers. The student has to select the answers he/she thinks to be true; all other alternatives must remain unchecked. The scoring is not obvious. We decided to use a very strict policy: for each alternative answer correctly checked or unchecked the student gains points, for incorrect checkmarks he/she loses the same number of points. So if half or more of the answers are wrong, no points will be given. The results are shown both as a bar graph (how many students have correctly marked/not marked a specific answer) and as a line graph (how many students gained how may points). This type of quiz may also be used for "Which of the following statements are true?"-type of questions.

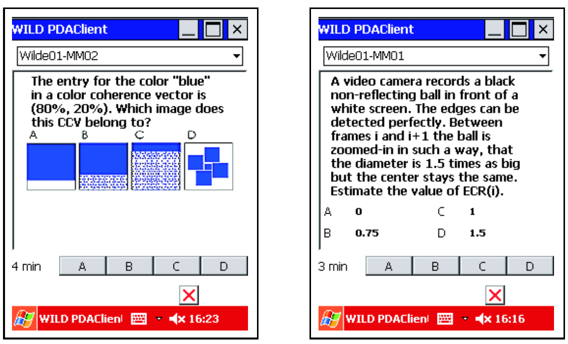


Fig. 3. Two Examples of simple Multiple Choice quizzes

- The *Fill-In statement* is a type of quiz, where the question itself is formulated as a statement with one word missing. This word has to be provided by the student. The student's answer is matched with a set of provided keywords that are considered correct (and score fully) and optionally against a second set of "almost correct" keywords that only give half of the points. A simple bar graph displays the results: how many students entered a correct, almost correct or wrong word.
- An *arithmetic problem* has to be solved mathematically and answered by entering a numerical value. Since the student's response is directly matched against the preset correct result, this is only useful for small, straightforward problems. To allow the automatic analysis of more complex problems, several alternative results may be defined and valued, which arise from small and predictable mistakes. The final results are shown as a bar graph with one bar for each alternative result and one for all incorrect answers.
- *Process ordering* quizzes present several steps of a certain process that are randomly shuffled. The student has to sort these steps by entering their numbers in correct order. Scoring is quite easy: the correct answer gives the maximum amount of possible points, one error (switching two steps or putting one step in the wrong position) gives half these points. The distribution of scores is again displayed as bar graph.

For post-processing, detailed statistics are stored including which student gave what answer, how much time did it take for him or her to answer, as well as the student's score. These statistics may be used for the automatic generation of ranking lists or to calculate part of a students grade. If analyzed, they may even help to improve certain quizzes, e.g., when the question has not been stated clearly.

IV. Evaluation

In order to evaluate the concept of the Interactive Lecture we developed a first prototype of the software. The following decisions were taken:

- Server and clients were developed in Java. Thus it is very easy to create a server, that instantly runs on the many different environments used in lecture halls.
- We use PocketPCs as students' devices because they are much faster and more powerful than PalmOS PDAs. Fur-

thermore, sufficiently advanced Java virtual machines are available for these handheld computers.

- The communication between clients and server takes place via IEEE 802.11b wireless LAN.

One of the major problems with Java, of course, is its low performance. In the earlier stages of the project this lead to the question whether a server written completely in Java would be capable to handle a sufficient amount of concurrent connections. To investigate this, a small program was developed that creates a variable number of bots which send random commands to the server in order to simulate the students' actions. The largest test run so far involved 210 bots, each simulating one students. The bots were split in groups of 30 and run on 7 different machines. Two computers were connected with wireless LAN, the rest with fast Ethernet. The bots were configured to send approximately 4.5 commands per minute (much more than a student would do) using the feedback service, and additionally disconnect and reconnect at random times. The server application ran on an off-the-shelf notebook with an 1 GHz CPU, 256 MByte of RAM and Linux as the operating system. After 5 hours the test run finished with the following results:

- All commands were processed without error.
- The response times (time between sending the request and receiving the parsed response) varied between 200 and 700 ms with an average of 320 ms.
- Disconnects and reconnects were handled correctly.

Much more interesting though is a first evaluation that took place in late January 2002. In this experiment we tried to figure out whether the Interactive Lecture really improves interactivity, heightens attentiveness and increases motivation. Furthermore we investigated the effect on the students' learning success.

A. Setting

To be as significant as possible, the evaluation was integrated into a real course ("multimedia technlogy" by professor Effelsberg, University of Mannheim). Two chapters (each covering one lecture) were prepared to utilize the quiz service described above. Each of these chapters was lectured twice, first as traditional lecture for comparison, then in the form of an Interactive Lecture.

Participating students were split into two groups: each group was to attend one chapter using interactive devices, and the other chapter without. This lead to the examination schedule as shown in Table I. Thus we were able to directly compare rating and learning success of traditional lectures and the Interactive Lecture.

To obtain the values needed for comparison, each student had to complete two questionnaires: One questionnaire at the beginning of the experiment asked for some personal information and tested the already existing knowledge with nine questions regarding the upcoming chapter of the course. The second questionnaire was handed out at the end of the lecture. It again tested the knowledge by posing the same nine questions in order to derive the relative knowledge gain. In Addition the students were asked to rate several items regarding the lecture itself as well as the quiz service if applicable.

Topic	Operating Systems		Content Analysis	
Quiz service utilized?	Yes	No	No	Yes
Student group	A	B	A	B
Number of participating students	16	28	17	21

TABLE I
Examination schedule for the evaluation

B. Realization and Technical Results

Only a few introductory words were needed to help the students start their clients, connect to the server and manage the quiz client interface. After a first simple test quiz to ensure that server and clients were working properly, the regular lecture started. The process so far (including the troubleshooting of some minor technical problems) took approximately 10 minutes.

During the lecture 9 questions were sent to the students in three blocks of 2-4 questions. All these questions were successfully transferred to the students and the students' answers were stored error-free, which could be proved by analyzing extensive log files on the server and client sides after the event. After each block the teacher could bring up the results simply by pressing a button on his user interface.

Even though only a small group of students participated in this evaluation a wide range of platforms were used: PocketPCs and notebook PCs running different Windows systems as well as Linux. The server itself ran on a notebook PC under Windows 98 that was connected by fast Ethernet. All clients were served equally well with response times well under 300 ms and no transmission errors at all.

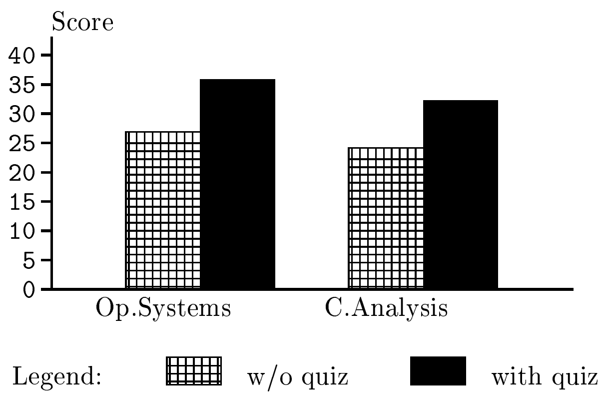
C. Results

The evaluation provided four classes of results: first, the students' opinion of the lecture itself, both as a traditional, unidirectional event and as an Interactive Lecture. Second, the students' rating of the quiz service. Third, statistics characterizing the learning success of the students with and without the utilization of the quiz client. Finally, we received much approval, criticism and many new ideas during a group discussion that took place immediately after the evaluation with all participating students.

Item:		*M*		*SD*		*p*
	Top.	**trad.**	**I.L.**	**trad.**	**I.L.**	
I'm satisfied with my learning success today	OS	2.00	2.80	0.71	0.41	<0.001
	CA	1.59	2.10	0.71	0.72	<0.037
The lecture today was interesting	OS	1.32	2.60	0.85	0.51	<0.001
	CA	1.35	2.50	0.70	0.69	<0.001
I had the impression that I was able to participate actively in the lecture	OS	0.97	2.27	0.76	1.03	<0.001
	CA	0.71	2.10	0.77	0.97	<0.001
I was particular attentive during today's lecture	OS	1.72	2.60	0.79	0.63	<0.001
	CA	1.47	2.25	0.87	0.55	<0.002
I have learned more in this lecture today than in other lectures	OS	1.24	2.33	0.72	0.90	<0.001
	CA	1.00	1.95	0.92	0.89	<0.003

TABLE II
Rating of the lecture (selected items)

In Figure 4 the students' rating of the lecture is shown (*M* stands for median and *SD* for standard deviation). The score shown is the sum of 13 different items, which had to be rated between 0 (does not apply) and 3 (fully applies), so the maximum score that could be reached was 39. All items were formulated in a way that a higher value was better than a lower value. As one can see, regardless of the lecture's topic, the score of the Interactive Lecture is much higher (>25%) than the score of the same lecture presented in the traditional way. Since the calculated significance p considering the increase of score between the two types of lecture is below 0.001 (i.e., there is a chance of less than 0.1% that one is wrong when assuming the given hypothesis), it is safe to say that the students as a whole considered the quiz service as a very valuable addition to the lecture.



Topic	**IL?** *)	***M***	***SD***
Operating Systems	no	24.60	4.43
	yes	33.27	5.71
Content Analysis	no	22.18	6.14
	yes	30.00	5.82

*) IL = Interactive Lecture

Fig. 4. Rating of the lecture with and without quiz service

A selection of some representative items can be found in Table II. For every single item the scores of the Interactive Lecture are higher than those of the traditional lecture. Particularly interesting is the third item (*active participation*). The students obviously had the opinion that they were much more actively involved in the Interactive Lecture than they had been before.

Another section of the questionnaire was designed to ask the students' opinion about the quiz service itself. It was composed of eight items, which again had to be rated between 0 and 3. Four selected items of this survey are shown in Table III. The total score (considering the students of both groups) was 19.94, which is a very remarkable result, since the highest (and most positive) possible score was 24. This very high rating was further supported by statements in the group discussions afterwards: almost all students considered the overall integration of the quiz service into lectures to be extremely useful and desirable.

To investigate the effect of the quiz service on learning success, we approximated the absolute knowledge gain by asking nine question regarding the respective topic at the beginning and the end of each lecture. These small tests were rated and compared; the results are shown in Figure 5.

The very obvious result is that in either case the students have indeed gained knowledge (with $p < 0.001$). However, it is far less evident whether they have learned *more* when using the quiz service. Analyzing the statistical results, a slight tendency that the learning success was indeed higher in the Interactive Lecture may be accounted for, most notably in the *operating systems* chapter. But this is not significant with sufficient confidence.

This result may have been caused by several weaknesses of the evaluation process. A major problem was the operationalization of the knowledge gain, which had been very inaccurate due to the short period of time in which the evaluation took place. More questions covering a wider area of

Item:	***M***	***SD***
I'm satisfied with my learning success today using the quiz service	2.19	0.82
The questions posed today within the quiz service were helpful for gaining knowledge	2.58	0.50
I think, that the quiz service helped me to learn today's topics	2.58	0.69
I consider the integration of the quiz service in today's lecture important	2.58	0.69
total score	**19.94**	

TABLE III

Rating of the quiz service (selected items)

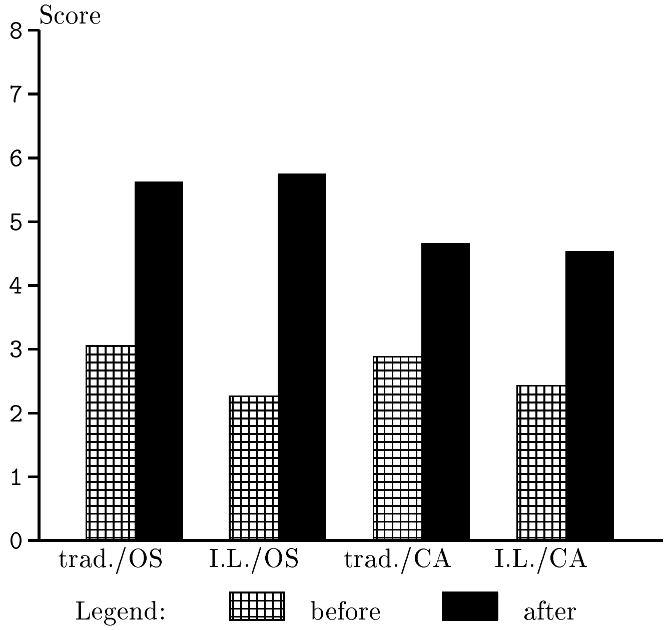
content would certainly provide better and more significant results. Furthermore only about 30 students participated regularly, so our sample was very small. Last but not least, the course in which the evaluation was carried out had the problem that the students were already very happy with it in its traditional form, so that the actual difference in the rating/learning success of a traditional lecture versus the Interactive Lecture was difficult to determine.

V. Conclusion and outlook

We have presented a technical framework to greatly improve interactivity for students in traditional lectures. This is done by equipping the audience with small, unobtrusive devices, with which several interactive services, such as hand raising, online-feedback and online-quiz, may be utilized. Since this new type of bidirectional communication is entirely based on electronic transmission, it is easily expandable for synchronous distance education. We focused on using standard technology that creates as little mental overhead as possible and is easy to integrate into existing lecture halls without requiring any construction work.

We also presented the results of a first experimental tryout. In late January 2002, we tested a prototype implementation of the quiz service with several students in a real course for about two weeks. When using our tools, the students were much more attentive and interested. They regarded the service generally as useful and desirable.

In the future several more extensive evaluations in different courses are planned, most notably courses that do not relate to computer science. In this way, we try to determine the effect of the Interactive Lecture on students with different study courses and varying experiences with computers both in early and late stages of their studies. Additionally, we will test further services in addition to the quiz and try to find out which combination of services is best for what type of lecture.



Topic	IL? *)	before		after	
		M	***SD***	***M*** (△)	***SD***
Operating Systems	no	3.06	1.22	5.65 (+2.59)	1.81
	yes	2.27	1.16	5.77 (+3.50)	1.16
Content Analysis	no	2.88	1.50	4.68 (+1.80)	2.00
	yes	2.45	1.30	4.55 (+2.10)	1.90

*) IL = Interactive Lecture

Fig. 5. Learning success with and without quiz service

References

[AAB+98] G.D. Abowd, C.G. Atkeson, J. Brotherton, T. Enqvist, P. Gulley, and J. LeMon. Investigating the capture, integration and access problem of ubiquitous computing in an educational setting. In *SIGCHI'98, Los Angeles, CA*, 1998.

[AAF+96] G.D. Abowd, C.G. Atkeson, A. Feinstein, C. Hmelo, R. Kooper, S. Long, N. Sawhney, and M. Tani. Teaching and Learning as Multimedia Authoring: The Classroom 2000 Project. In *ACM Multimedia '96, Boston, USA*, pages 187–198, 1996.

[Bli00] D.A. Bligh. *What's the use of lectures?* Jossey-Bass Publishers, San Francisco, 2000.

[DGL+96] R.J. Dufresne, W.J. Gerace, W.J. Leonard, J.P. Mestre, and L. Wenk. Classtalk: A Classroom Communication System for Active Learning. *Journal of Computing in Higher Education*, 7:3–47, 1996.

[DLB+98] R.C. Davis, J. Lin, J.A. Brotherton, J.A. Landay, M.N. Price, and B.N. Schilit. A Framework for Sharing Handwritten Notes. In *UIST'98, San Francisco, USA*, pages 119–120, 1998.

[DLC+99] R.C. Davis, J.A. Landay, V. Chen, J. Huang, R.B. Lee, F.C. Li, J. Lin, C.B. Morrey, B. Schleimer, M.N. Price, and B.N. Schilit. Notepals: Lightweight Note Sharing by the Group, for the Group. In *CHI'99, Pittsburgh, USA*, pages 338–345, May 1999.

[GBL99] S. Greenberg, M. Boyle, and J. LaBerge. PDAs and Shared Public Displays: Making Personal Information Public, and Public Information Personal. *Personal Technologies*, 3(1), March 1999. Elsevier.

[MSG98] B.A. Myers, H. Stiel, and R. Gargiulo. Collaboration Using Multiple PDAs Connected to a PC. In *CSCW'98, Seattle, USA*, pages 285–294, 1998.

[PMMH93] E.R. Pedersen, K. McCall, T.P. Moran, and F.G. Halasz. Tivoli: An Electronic Whiteboard for informal Workgroup Meetings. In *InterCHI'93, USA*, pages 80–87, 1993.

[Rek97] J. Rekimoto. Pick-and-Drop: A Direct Manipulation Technique for Multiple Computer Environments. In *UIST'97, Banff, Canada*, pages 31–39, 1997.

[Rek98] J. Rekimoto. A Multiple Device Approach for Supporting Whiteboard-based Interactions. In *CSCW'98*, pages 344–351, April 1998.

[RP02] J. Roschelle and R. Pea. A walk on the WILD side: How wireless handhelds may change CSCL. In *CSCL 2002*, January 2002.