1 Introduction

Conventional lectures are connected with fundamental didactic problems. Particularly in large meetings, it is difficult for the lecturer to respond to individual questions or remarks. Furthermore, it is difficult to maintain the students' attention permanently, and to enable deeper cognitive processes. From the students' point of view, communication with the instructor is very restricted in mass meetings as well.

At the University of Mannheim, we developed the new teaching-learning-scenario of the Interactive Lecture to enable a a bi-directional synchronuous communication between students and lecturer on the basis of a Wireless Local Area Network. Within this scenario, all students are equipped with handheld computers like PocketPCs or Palm PDAs and use different so called WILD (Wireless Interactive Learning Devices)-services which allow interactivity and adaptivity of the learning contents between all participants in lectures.

1.1 Didactic Relevance:

From a pedagogical standpoint, learning is an active process. Interactivity represents an opportunity for the learner to take a hand in shaping the informational, communicational and learning process rather than remaining a passive recipient; thus it has a great impact upon successful learning.

The lack of interactivity between instructors and students, respectively among the students themselves, is one point of criticism with regard to the traditional university lecture. In large teaching scenarios, more so than in more intimate ones, it is difficult for the instructor to address individual questions or comments in any depth, or to challenge the attention of the participants by means of more thoughtful questions. Also, even when such questions or feedback do constitute an essential aspect of the lectures, problems nonetheless arise: The traditional communication aids (for example, raising of hands, interjections) are of hardly any use in a large instructional scenario, since the student who does raise his/her hand will barely be noticeable in a crowd of many others. In addition, if not all participants are to be questioned individually, the only other procedures available, if indeed there are any at all, to guarantee a comprehensive consideration of students' questions are dichotomized feedback or else more time-consuming procedures. Thus, interactive components can only be realized in auxiliary laboratory exercises or tutorials, but not in the traditional lecture.

Mobile computers with wireless network access are an innovative way to achieve interactivity. Using mobile computers, participants can forward information to fellow participants or to the instructor more rapidly, "anonymously" and in more depth. The instructor can also address the participants more rapidly and directly. Moreover, with mobile computers information can be documented in greater detail, for example for analytical purposes or for the purpose of integrating archived information into other types of knowledge transfers.

Another advantage of lectures integrating the use of wireless devices by the students is the potentially adaptive behavior of the instructor. Adaptivity refers to the adjustment to the learning environment. Interactivity and adaptivity are closely related. As the adaptivity of a system increases, its interactivity will necessarily increase as well. Adaptivity is employed in an instructional-psychological context essentially to improve the learning process. For example, the instructor adapts explanations or curricula to the learners' current state of knowledge to achieve greater efficiency and efficacy of instruction by having the learners more deeply elaborate their knowledge. Empirical findings corroborate the effects of the most diverse learning-centered measures upon learning success. For example, tuning the learning content to the interests or goals of the learners will affect their learning success positively.

In summary, the increased inclusion of students into the scenario promotes their motivation, activates them and guides/focuses their attention. This, in turn, has a positive effect upon their knowledge gains, since deeper and faster processing of knowledge can take place during the process of continuous learning.

2 Architecture, implementation and tools

2.1 Architecture:

The WILD@Mannheim-Toolkit is designed as a classical client/server-application. As central part of the architecture the server (1) itself provides only the most basic functionality: connection management, user management and service management. The connection management establishes connections to the clients upon request, processes incoming and outgoing data and monitors the registered connections for broken links. The user management identifies individual users via password and stores personal information for internal and external use. Finally, the service management 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 (2) provide the intrinsic functionality that is visible to the user when

he starts his client and connects to the system. They are built as independent modules that must be loaded by the server at start-up.

As a rule the clients for the teacher and the (optional) moderator run on machines that are connected to the server via a traditional wired network (3). These clients are specifically designed to match the higher functionality these persons need to operate the interactive lecture, e.g. activating quiz rounds or answering questions asked by students using the call-in service. To avoid extensive use of wires, the students' devices (4) are connected with wireless LAN using one or more access points. The intended target devices are PocketPCs (e.g. Compaq iPaq, Casio Cassiopaia or HP Journada). These handheld computers are equipped with rechargeable battery packs that last at least for many hours operating time.

Special preparations have been made to allow scenarios with more than one server (5). A simple external interface program connects to two servers and ensures that at any time both servers have access to all data and all users while they still operate completely independent. Since the server allows more than one interface connection every imaginable server network is possible. This functionality is especially useful in distributed lecture scenarios in which the teacher's image, voice and presentation slides are broadcast via videoconferencing tools to one or more remote places.

The interface-technique is usable as well to connect an WILD-server to a supporting foreign architecture (6). Here the first efforts were made by creating a bridge between the "mlb" multimedia lecture board, an electronic whiteboard for distributed scenarios) and the WILD@Mannheim-system that may be used to send slides to the student's device and allow the student to remotely operate the telepointer of the mlb.

2.2 Tools:

Services may be divided into two categories:

- services to be used during the lecture:
  - Call-In: spontaneous questions can be put to the attention of the teacher or a moderator anytime
  - Quiz: short quizzes during the lecture heighten attention; student can utilize their newly acquired knowledge
  - Feedback: feedback can be sent to the lecturer during the entire lecture and not only at the end
- services to be used before or after the lecture:
  - Messaging: short messages may be sent between individual users to ask short questions or make appointments
  - Chat/Forum: solve individual problems with the help of many users

2.3 Implementation:

The whole projects has been developed in Java as this is the easiest and most reliable way to support a wide range of platforms. Indeed the server, the modules and most core applications, such as the interface, that are intended to run on high-end computers have been successfully tested on Linux, Solaris, Windows 2000/NT and Windows 9x systems. These applications make use of the currently most advanced Java technology (JDK 1.4.0).

The student's clients are written for and older, 1st generation Java version (Java 1.1.3) and thus compatible with Sun's PersonalJava (PersonalJava is a subset of Java that allows the development of virtual machines for small devices such as Palms and PocketPCs). Additionally the graphical user interface of these clients has been optimized to fit the small screen size of mobile devices (as a rule this is 240x320 pixels for PocketPCs). As a result these clients may be used on any operating system for PCs (including Notebooks, Tablet-PCs) as well as on PocketPCs.

3 Evaluations

All evaluations were performed by the research group Didactics and Evaluation in virtualized Learning (DEviL) which belongs to the department of education II at the University of Mannheim. DEviL is dedicated to attend, consult and evaluate multimedial teaching concepts.

Two experimental investigations of the new scenario were conducted. (in this semester, the third study is running). In a first trial in a computer science lecture (N=44), the quiz service was implemented for the use on mobile computers. The students participated either in an interactive or a conventional lecture session. The groups were compared regarding to acceptance and success in learning. With respect to acceptance, the

interactive condition was evaluated significantly better than the conventional one. Concerning the learning outcome the results for the interactive scenario were superior when compared to the conventional setting.

In the second study (N = 99), a long-term integration of the quiz service was implemented as well as an experimental application of the call-in-service. Again, the lecture was part of a computer science course. Besides, the lecture was transmitted to the University of Freiburg as a tele-lecture, and the students at the remote location were likewise included into the investigation actively. Additionally to acceptance and knowledge acquisition, data concerning current motivation and attention were obtained continuously in all meetings. The highly positive acceptance values of the preliminary investigation were replicated. Besides, a significant higher and faster learning increase was observed in the interactive condition.

The results highlight the potential of the *Interactive Lecture* scenario for didactic and technical improvements in higher education.

4 Downloads

4.1 WILD Software:

Here you can download the latest release of the WILD@Mannheim-toolkit. Please note that it is still a prototype implementation so it should not yet be used seriously in any courses (only for evaluation purposes). Two packages are available for download:

The PC Package (Server and Client) (v0.4final, released 12/18/2002, approx. 280 kByte) contains:

- the main server application
- the following services: Feedback, Messaging, Quiz
- the student client for Personal Computers or notebooks
- special clients for teachers and moderators

To use this package you must have a Java Runtime Environment installed (at least 1.4.0). Two small documentations that will help you get server and administration clients as well as the student client running are available as PDF.

The PDA Client Package (v0.4final, released 12/18/2002, approx. 65 kByte) contains:

- a multi-purpose client for the PocketPC (which may be used on a PC/Notebook too)
- support for the following services: Feedback, Messaging and Quiz

Since there is no native Java support integrated in the PocketPC operating system, you need to buy the commercial PersonalJava Runtime Environment Jeode from Insignia (it may be included in your software pack which was delivered with your device). As an alternative, you may want to try Sun's personal java reference implementation, which is freely available in the developers section of their homepage. The client software is tested with Sun's VM as well, but you may encounter some problems (for further information read the SunJava.readme file included in the client package). A small documentation that will help you to install the files on the mobile device and get the client running is available as PDF.

4.2 Contact:

Please send bugs, requests or comments to Nicolai Scheele (scheele@informatik.uni-mannheim.de)

5 Publications

5.1 Journal articles:

- Wessels, A., Fries, S., Horz, H., Scheele, N. Effelsberg, W: (eingereicht). Interactive Lecture: Effective Teaching and Learning in Mass Meetings with Wireless Networks. Computers in Human Behaviour.

5.2 Refereed Conference Contributions:

- Martin Mauve, Nicolai Scheele, Werner Geyer. *Enhancing Synchronous Distance Education with Pervasive Devices.* Accepted at Informatik 2001 (Jahrestagung der GI und der OCG), Wien, 2001.
- Martin Mauve, Nicolai Scheele, Werner Geyer, Wolfgang Effelsberg. *Ubiquitous Computing in Education.* Proc. of the 8th International Conference on Communication and Control (COMCON8), 2001.
- Scheele, N., Mauve, M., Effelsberg, W., Wessels, A., Horz, H. Fries, S. (2003). *The Interactive Lecture - A New Teaching Paradigm based on Ubiquitous Computing.* Poster accepted at CSCL '03, Bergen, Norway,2003

5.3 Technical Reports:

- Scheele, M., Mauve, M., Effelsberg, W. , Wessels, A. Fries, S. (2002). *The Interactive Lecture: A New Teaching Paradigm based on Ubiquitous Computing.* Submitted for publication. Also Technical Report 6/2002, Department of Computer Science, University of Mannheim.

5.4 Theses:

- Nicolai Scheele. *Interaktive Lehre durch Einsatz mobiler Endgeräte.* Master's thesis, 2001.

5.5 Presentations:

- Wessels, A., Fries, S. Horz, H. (2003). *WLAN-unterstütztes Lehren und Lernen in interaktiven Vorlesungen.* Vortrag gehalten auf der 64. Tagung der Arbeitsgruppe Empirisch Pädagogische Forschung (AEPF), 17.3.-19.3.2003 in Frankfurt.
- Effelsberg, W. Wessels, A. (2002). *WILD - Wireless Interactive Learning Devices.* Invited Presentation at the San Francisco State University, Center for the Enhancement of Teaching (CET), November 2002.
- Wessels, A. Horz, H. (2002). *Interactive Lectures: Teaching and Learning in Wireless Networks.* Invited Presentation at the University of Stanford, Stanford Center for Innovations in Learning (SCIL), November 2002.
- Effelsberg, W., Scheele, N. Wessels, A. (2002). *WILD - Wireless Interactive Learning Devices. Design, Implementation and Experience.* Presentation at the University of Stanford, Stanford Center for Innovations in Learning (SCIL), October 2002.
- Wessels, A., Fries, S. Horz, H. (2002). *Interaktive Vorlesungen: WLAN-unterstütztes Lehren und Lernen in interaktiven Vorlesungen.* Vortrag gehalten auf dem 43. Kongress der Deutschen Gesellschaft für Psychologie, 22.9.-26.9.2002 in Berlin.
- Wessels, A., Fries, S. Horz, H. (2002). *Interactive Lecture: Teaching and Learning in Wireless Networks.* 5th Workshop of the European Association for Research on Learning and Instruction (EARLI) SIG 6 Instructional Design Instructional Design for Multimedia Learning. Erfurt, June 27th 29th,2002.