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NEW TEACHING AND LEARNING TECHNOLOGIES FOR INTERACTIVE LECTURES

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Abstract

Conventional lectures in large classrooms come with fundamental didactic problems due to a lack of interactivity and feedback opportunities. In an *interactive lecture* each student is equipped with a light-weight, mobile device that can be used to interact with the lecturer during the lesson, thus creating an additional channel of communication. These devices support new teaching and learning paradigms such as participatory simulations. We present our experiences with the usage of mobile devices in lectures. After discussing the didactic benefits of interactive lectures, we introduce the software toolkits used in our scenarios, we highlight selected tools such as a quiz tool or a support tool for participatory simulation, and present major results from six pedagogical studies we have conducted.

Key Words

Mobile learning, mobile technology in education, interactive lecture, participatory simulation.

1. Introduction

Many new approaches based on emerging computer technologies were introduced in recent years supporting the learning of students in lectures. The aim of these approaches is the improvement of the quality and effectiveness of university teaching by using multimedia elements. With the help of appropriate new teaching and learning procedures it is expected to achieve a better adjustment to individual learning needs, learning rates and time budgets of the students. For the instructors, a better efficiency of teaching is intended.

But despite the various multimedia projects and efforts on the part of dedicated instructors, the introduction of educational media only partially led to a modernization of the actual teaching scenarios. This is particularly evident when looking at the classical university teaching-learning scenario: the *classroom lecture*. Lectures in universities have profited from many technical advances over the last few years. Blackboards were replaced by overhead projectors which again were substituted by video projectors and electronic whiteboards. Most lecture halls are nowadays 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 teaching paradigm has remained largely unchanged. The main disadvantage of traditional lectures is the *lack of interactivity*: they can be characterized as situations in which a teacher presents new information to the learners without guiding their learning processes. The limited interaction possibilities in lectures cause a set of problems regarding students' attention and motivation, as well as a lack of quick adaptation of the lecturer's instruction.

Lecturers often attempt to overcome these problems by asking questions to trigger feedback on how well the students have understood the presented material, as well as to provoke them to actively participate. In lectures with a large audience this is problematic since only a few students are able to interact with the lecturer. The overwhelming majority will not profit from this form of interactivity. From a pedagogic-psychological view, learning (in lectures) should be reconstructed as an active process [1,2]. Interactivity represents an opportunity for the learner to take hand in shaping the informational, communicational and learning process rather than remaining a passive recipient. Thus, an active involvement of the learners has a great impact upon successful learning [3].

Finally, a fundamental problem in traditional lectures is the required continuous attention of the learner over 60 to 90 minutes. Usually, the attention span of a learner is only about 20 minutes [4]. Subsequently, an activity change should take place in order for the students to keep their attention up (e.g., a change between lecturing and discussion phases). However, in the traditional large classroom scenario, such activity changes are rare, and if ever done, the lecture elements depend exclusively on the specific ability of the lecturer [3].

But despite these didactic shortcomings, the classroom lecture still is an important and common teaching scenario since it has also advantages compared to other settings. Especially important is the economic aspect: Only in lectures an individual lecturer can impart knowledge to a large number of students at the same time. Furthermore, the classical teaching form is technically flexible and therefore easily adaptable to different audiences, topics, timetables and available technical devices. Also, a flexible integration into the curriculum without careful planning can be realized, which would not be possible with e.g. book-bound material.

We conclude that there are strong reasons to work on the *improvement of the large-classroom scenario*, in particular to create a new (more interactive) version. An innovative approach to improve interactivity and to realize a bi-directional, synchronous communication in lectures is to equip the students with small electronic devices such as handheld computers. To avoid cost-intensive modifications of the lecture hall, the handheld PCs and the server are connected by a wireless LAN. The handheld devices communicate with the computer of the lecturer and thus allow exchanging information with the lecturer at any time, without disturbing the lecture.

It is not only important to increase the communication between teacher and student but it is also desirable to increase the *activity*, *motivation* and *attention* of the students. A *participatory simulation* is a new didactic concept, enabled by handheld computers and wireless communication, where students take an active role in a computer-based simulation. A dynamic and complex problem of the real world is mapped to a simulation model. The model is implemented in software on the computers. Students observe the model in the classroom and make decisions; they actively discover and understand the impact of their activities and learn the processes of complex systems in the simplified model of the simulation. A major advantage of participatory simulations is the fact that the level of activity of the individual can be high even in large groups. The exchange of experience and a discussion in small groups within or after the simulation help to improve the understanding of the simulated system.

Two departments at the University of Mannheim (Computer Science and Educational Science) conduct the *Lecture Lab project* [5] to create a new form of multimedia-enhanced teaching along these lines: the **Interactive Lecture**. We have designed and implemented a full-featured software system and performed several major field studies to evaluate our concept. We worked in close cooperation with several leading labs, e.g., the *Stanford Center for Innovations in Learning* in California.

In the following, we describe the possible usage of mobile devices in large learning environments, present the scenario of the Interactive Lecture as well as our own technology called *WIL/MA* (Wireless Interactive Learning at the University of Mannheim). We illustrate how participatory simulations can support the teaching and learning and give an example of a stock exchange simulation for graduate students in financial theory and an Internet packet routing simulation for students in computer science. We finally give an overview of the results of six extensive experimental field studies which we have carried out in lectures of computer science and educational science in order to investigate the motivational and cognitive effects of our new teaching-learning method.

2. Mobile devices in lectures

A number of projects focusing on using mobile devices in lectures in order to enhance learning and teaching have evolved over the last few years. Most of the projects have specific ideas about what aspect of the lecture they intend to improve and how to cope with arising problems. Following is a short list of past and ongoing projects, along with a description of the basic ideas behind them.

Classtalk [6] is a well-known Classroom Communication System by Better Education Inc. For the better involvement of every single student, the teacher transfers three to four Classtalk tasks per lesson to the students' devices; these can be calculators, organizers or personal computers, and they are often owned by the students. *ClassInHand* from Wake Forest University turns a PDA equipped with a wireless card into a web server as well as a presentation controller and a quizzing and feedback device for the lecturer [7]. Its major components are the Presentation Control and Web Server for the PocketPC. The Web Server enables concept tests (quizzes), textual feedback, a feedback meter and easy document posting.

ConcertStudeo a project of the Fraunhofer Institute *IPSI* uses an electronic blackboard combined with handheld devices [8]. It offers exercises and interactions such as multiple-choice quizzes, brainstorming sessions, queries or role-plays. The collection, analysis, and presentation are done by the software. Specifically designed for online feedback is *CFS* (the *Classroom Feedback System*) from the University of Washington [9]. It allows students to post annotations directly on lecture slides.

A different approach to improve the learning success and the motivation of students is based on *participatory simulation*. A participatory simulation is a role-playing activity that helps to explain the coherence and behaviour of complex dynamic systems. Global patterns emerge in participatory simulations from local interactions of users [10]. A major idea of participatory simulations is the concept of learning through doing. Students participate in an active way, analyze available information, make decisions, and see the outcome of their actions. This increases the motivation, and the learning success improves [11]. Simulations were realized with paper and pencil in the past, but the technological advances now allow a new type of simulation. *NetLogo* [12] is a software-based environment for the development of participatory simulations for PCs. A major advantage of this technology is that simulations can be re-played, analyzed and compared with previous simulations. With the rapid development of networking technologies, the NetLogo system was extended to support the participation of several human players. The extension is called *HubNet* [13]; it supports PCs and mobile devices for input and output.

3. Wireless Interactive Learning at the University of Mannheim

As discussed above, there are many different ways to take advantage of mobile devices for *improving interactivity* in the lecture hall. However, we discovered a number of common flaws in most of the earlier work:

- Most projects offer a *unidirectional flow of communication* from the students to the teacher. The communication in the opposite direction is based on traditional means, so that individual feedback is not possible.
- Most systems do not support *personalization*, but students prefer an adaptation to the individual students' needs.
- The software in most projects is *static*, which leads to a limited number of possibilities for interaction. Even undesired functionalities cannot be deactivated in several earlier projects.
- Most systems support *small working groups* with 20 or 30 students. Their solution is often not applicable in large lecture scenarios, e.g., in lecture halls with 150 or more students.
- We do not restrict our software to specific *computer platforms* (hardware or software), but support a wide range of different students' devices.

Most of the earlier work has focused on one or more of these specific issues. Our *Wireless Interactive Learning* (WIL/MA) software [5] attempts to solve these problems: the same basic software architecture can accommodate many different interactivity services ranging from quiz tools to participatory simulations.

Three prerequisites are required for the WIL/MA system: The first requirement assumes that *small pocket-sized computers* are used, which can be carried around easily. The students' tables in some lecture halls are too small to use printouts and large notebooks at the same time. The support of *wireless communication* in the lecture halls is the second prerequisite of the WIL/MA software. We focus on Wireless LAN (802.11b) due to the fact that it is available in all lecture halls on our campus and supported by a large number of mobile devices. A data rate of 11 MBit per second and the indoor communication range of 70 meters are sufficient for the interactive lecture scenario, providing access for more than 100 students simultaneously. The third assumption considers the fact that students use different types of computers to participate in an interactive lecture. Therefore, we selected JAVA as a *common platform-independent computer language*. Our system is written in Java and portable to almost all modern mobile devices.

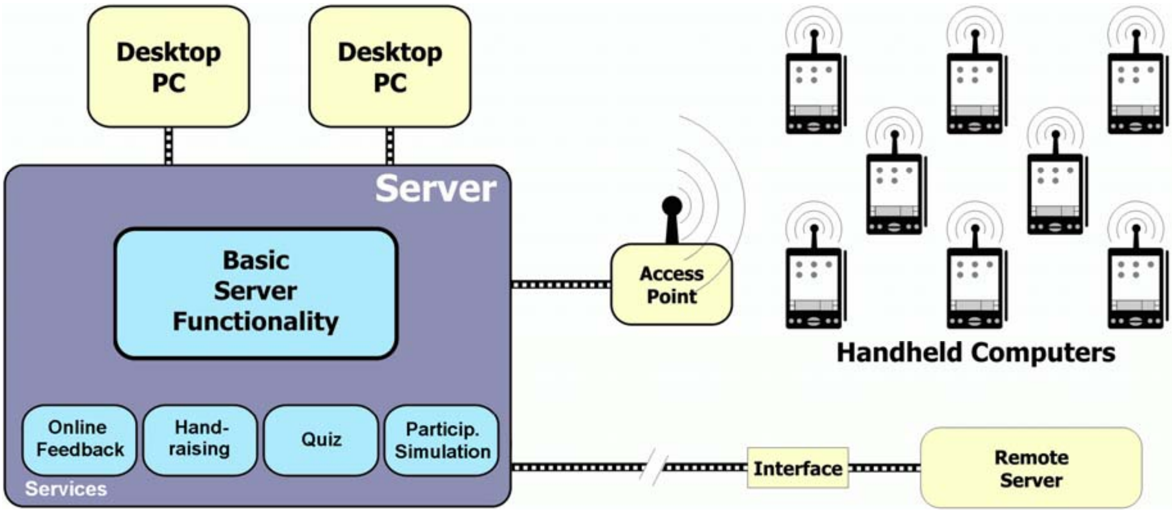

Figure 1. The WIL/MA architecture

3.1 System Architecture

The WIL/MA system is designed as a classical client/server application (see Fig. 1). As the central part of the architecture, the server provides all the fundamental functionality: management of the connections, users, and services. All functionality which is visible to the users is bundled into *services*. Services are built as independent modules which are loaded by the server and the clients at start-up time; for each service there is a server-module, a teacher-module and a student-module. The *server*-modules are the central part of a service. They have to aggregate all incoming data, analyze the information and broadcast trimmed data packets in various ways back to the teacher and each individual student. While the *teacher*-module focuses more on editing various aspects of the service as well as the display of analyzed data, it is more important for the *student*-module to display prepared material appealingly and to provide an intuitive user interface.

Several services are implemented so far, e.g., a *quiz tool*, an *online-feedback tool* and support for *participatory simulations* (see Fig. 2 for screenshots of these services). The *quiz tool* allows the teacher to pose questions (that possibly include graphics or animations) about actual lecture contents and transfers them via wireless LAN to the audience. The students work on them and send their answers back to the lecturer's computer. After a timeout, the cumulated results are presented graphically on the projector. In this way the lecturer and students gain a representative feedback on the newly acquired knowledge. Apart from two different multiple choice question styles (only one correct answer, multiple correct answers), we integrated clickable images to ask the student to point into a certain area of a picture as an answer (for example: "point at the location of Moscow on a map of Russia"). Fill-in questions make it impossible for the student to accidentally guess the right answer of a mathematical exercise.

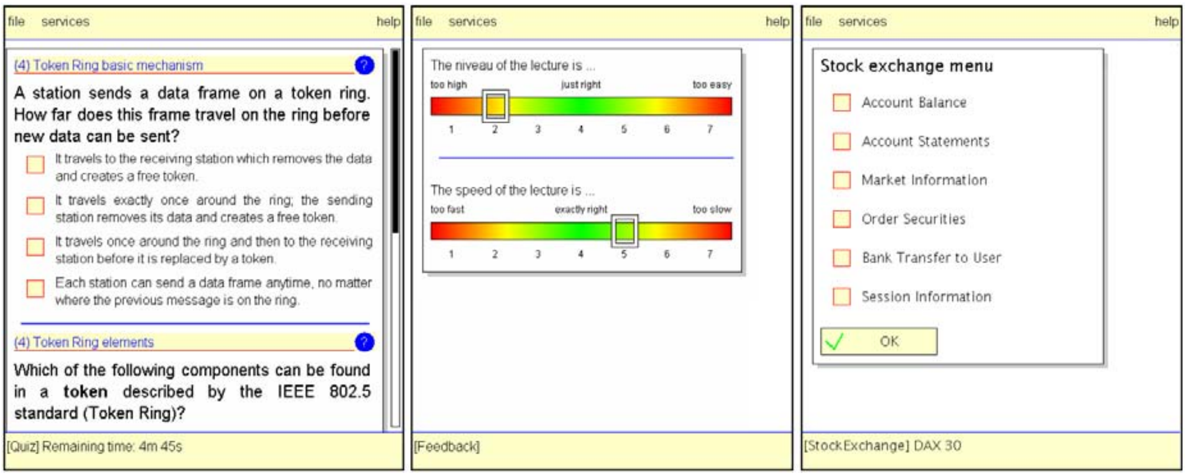

Figure 2. Screenshot of the students' client showing a *quiz* (left), *feedback* (center) and a *participatory simulation of a stock exchange* (right).

3.2 Implemented Services

The *feedback tool* delivers direct and systematic feedback to the lecturer about different aspects of the lecture from all students, who can then instantly adapt his/her presentation style to the new situation. An aspect – or category – could be the speed or the level of the lecture, so students can ask the teacher during the lecture to progress more slowly or discuss a certain topic in more detail. Also, technical issues can be used as a feedback category; for example, video or audio distortions in tele-presence scenarios can be discovered much sooner or the students can be asked to complain, when their learning environment is suboptimal (because other students are too loud in the last rows or bright sunlight makes it impossible to read the projected lecture slides).

3.3 Support of Participatory Simulations

A participatory simulation follows the general structure of the WIL/MA system and therefore provides server and client functionalities for students and for the lecturer. The relevant features of the system are exemplified by a *stock exchange simulation*. This simulation was designed for graduate students in business administration to improve their understanding of finance theory and especially of the pricing of securities [14]. Users taking part in the computer-based simulation become private investors who are able to buy and sell stocks, bonds or stock options. The task of the teacher is to configure the general simulation, e.g., to define data such as market information or securities. By starting the simulation, a server process is initiated which is responsible for simulating the stock exchange based on configuration parameters like available companies or securities, market data, market indices and company news. During the simulation, the server repeatedly computes new market data and security prices.

The client provides an interface that allows the users to act as private investors. Fig. 2 (right) visualizes the basic client menu. E.g., viewing the account balance, users can see the amount of cash and the list of securities in their portfolio, including the number of stocks and their total value. At the end of the simulation, a ranking is sent to all users, showing all participants with their current portfolio value. The economic competition is a major motivating factor for the students.

Table 1
Overview of the experimental studies

Semester	Course	Number of interactive students	Objectives
Winter 01/02	Multimedia Systems	44	Technical and didactical trial
Summer 02	Computer Networks	99	Comparison: traditional vs. interactive lecture
Summer 03	Computer Networks	54	Feedback variation for quizzes
Winter 03/04	Pedagogical Psychology	69	Individual vs. social benchmark in quizzes
Summer 04	Computer Networks	68	Observation of a "normal" interactive lecture
Winter 04/05	Pedagogical Psychology	68	Effects of direct feedback possibilities
Since Summer 05	Computer science courses	21 - 85	Regular use of the WIL/MA tools

3.4 Choosing the Best Device

In our experience, the best devices for the Interactive Lecture are modern, light-weight *notebooks* (alternatively TabletPCs) and *PocketPCs*. Notebooks are capable of running almost all software designed for modern computers. PocketPCs are favoured by most students because they are very small and easy to carry. Also, they do not take up as much table space as a notebook computer so that printed scripts, etc. can still be used. Although often praised in the literature, we think that *mobile phones* are not ready yet to be used in interactive learning scenarios. Featuring only very small screens and either very expensive or very limited connectivity, today's mobile phones can only be used for the most basic services. We expect that this will also change in the near future, as cell phones and PDAs are merging rapidly [15].

4. Experimental Field Studies and Experiences

Our WIL-MA technology, which is available under the Open Source license and free for download [5], was developed to support interactive lectures with mobile devices. Different services like hand-raising, feedback, a quiz tool or the participatory simulation are available. We have conducted six extensive experimental studies in order to learn about flaws in our software, investigate the effects of mobile devices in lectures with respect to motivational and cognitive impact, and to develop guidelines for teachers who want to use these tools. Four of the studies were carried out in computer science lectures and two in educational science lectures. Table 1 gives an overview of the experimental studies. We are using the WIL/MA system in larger computer science courses since Summer 2005 on a regular basis.

4.1 Technical and Conceptual Results

We analysed technical limitations of the WIL/MA system in the first experiments. The system works very reliably, and the capacities (CPU power, memory, storage capacity) of the server (a standard notebook) and the mobile devices are no limiting factors. On the other hand, the wireless network can be a bottleneck: Network problems occurred if more than 145 clients used the system simultaneously. A second access point or an update to current network technology solves this problem. Another challenge is the battery lifetime of the Pocket PCs. If wireless LAN is enabled most devices do not run longer than 90 minutes, so that a recharge between two interactive lectures is mandatory. We expect an increase of the battery lifetime in the near future, similar to the improvements in notebooks.

Table 2
Selected answers from the questionnaire comparing traditional and interactive lectures

Question	Traditional lecture	Interactive lecture	Significance
I am content with my learning success	77.7 %	87.3 %	$p = 0.030$
The lecture was diversified	65.0 %	77.7 %	$p = 0.072$
I had the opinion that I could participate actively	38.0 %	66.7 %	$p < 0.001$
I have learned more than in other lectures	62.0 %	71.3 %	$p = 0.162$
The lecture was generally very good	76.3 %	85.7 %	$p = 0.083$
Sum of all 16 questions	72.0 %	80.0 %	$p = 0.005$

4.2 Interactive Lectures in Computer and Educational Sciences

In an experimental study a first prototype of the WIL/MA tools was technically and empirically tested in a computer science lecture by comparing two wireless LAN-supported sessions with two conventional lectures of the same topic. The 44 students of this lecture participated in an interactive and in a conventional lecture session and the groups were compared with respect to acceptance of the teaching method and success in learning. Regarding the acceptance, the interactive condition was evaluated significantly better than the conventional one. Besides, students reported higher levels of assumed attention, activity and estimated learning success in the interactive condition. Objective measurements indicated better learning results in the interactive condition, though the values fall just short of significance. And finally, there was no measurable distraction in the interactive lectures. Overall, the results were very encouraging.

As the next step, in summer semester 2002, a long-term integration of the system was realized as well as an application of the scenario within a tele-lecture [16]. The computer science lecture was transmitted as an MPEG-stream via the Internet to a lecture hall at another German University. Just like the students in Mannheim, the students at the remote location were included into the scenario and the study. The lecture was split into a conventional and an interactive phase, the latter consisted of eight consecutive sessions. For all 99 students the acceptance of the two teaching methods and their learning increases were quantified. We could replicate the good acceptance scores of the first study: again, the interactive sessions were rated very well and were superior in their acceptance compared to the conventional lecture. Table 2 presents a selection of the questionnaire. The significance value p in the last column has the following meaning: We assumed the hypothesis that "*the interactive lecture is rated better than the traditional lecture*". p defines the chance that this assumption is not correct. In average, this chance is less than 0.5 percent for all 16 questions.

We used online surveys, assignments and group discussions to measure the *motivation* of the students in interactive lectures. Based on a very high significance ($p < 0.001$) the students like interactive lectures and most students are much more attentive. Advanced question types (e.g., clickable images) were considered exceptionally valuable. We did not only want to identify the motivation, but used pre and post knowledge test to measure the *learning success* of the students. Fig. 3 visualizes that the students learned noticeably more in the interactive phase compared to the traditional phase ($p < 0.001$). The figure on the left visualizes the outcome of the second experiment in Summer 2002 which compares the learning increase of the traditional and the interactive lectures. Arrows indicate a significant learning increase.

The next step was to carry out interactive lectures with participants who are not as technical experienced as computer science students. Therefore, we implemented the scenario within two

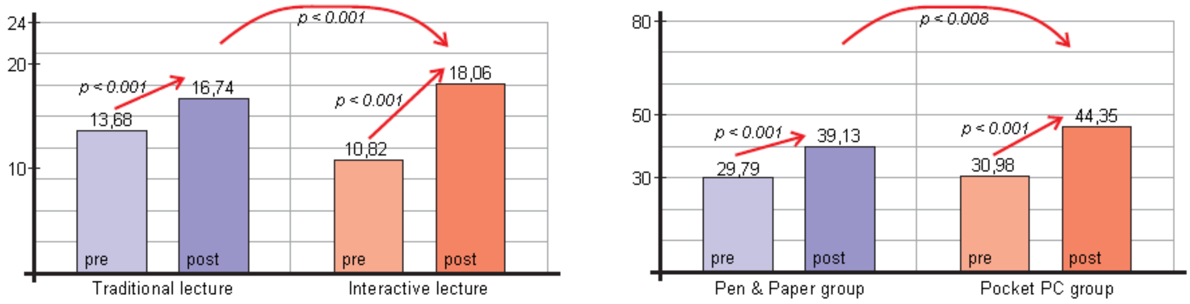

Figure 3. Evaluation of the learning increase in conventional and interactive lectures with mobile devices. The numbers indicate the average number of correct answers, the arrows a significant learning increase.

educational science lectures in order to generalize previous findings and to extend the research by investigating a technically less experienced sample. In the first interactive educational science lecture in winter semester 2003/04 the focal point of our research was the question if and how a variation of an individual feedback to the quiz performance would affect cognitive and motivational variables. 69 of the 214 participants of the lecture were equipped with mobile computers. The other students participated in the interactive sessions with a paper-and-pencil procedure. Fig. 3 on the right compares a pen-and-paper group with a PocketPC group.

4.3 Participatory Simulations

In addition to the Interactive Lecture scenario, three different participatory simulations were implemented and tested [17]. The first simulation is based on the WIL/MA software architecture and implements a stock exchange that was designed for graduate students in financial theory. The participants get market information and have the possibility to trade different kinds of securities. Each student manages a securities account and tries to increase its value; this is done in competition with the other students. The competition is a major factor for the motivation of the students. They have to be active to increase their profit and can benefit from analyzing market information and understanding basic factors about the pricing. Although the students can see the success of their investment strategy on the changing value of their portfolio, the more profound experience gain is based on a discussion of their strategies in groups. In general, the motivation of the students in our experiment was very high.

We developed a second stock exchange simulation [17] based on NetLogo/HubNet in order to compare it with our WIL/MA system. The full functionality of the WIL/MA system could not be re-implemented due to missing features in NetLogo such as dynamic screens, menus or limited possibilities for interaction. Stocks are traded by artificial or human agents in this simulation. The teacher defines a specific strategy for each artificial agent based on the readiness to take risks. It is possible to select agents that get additional insider information about the expected development of the prices of one stock.

One of the major strengths of NetLogo is the interface builder: Elements of the client window can be arranged by *drag-and-drop*, and it is very easy to add code to the elements. A graphical visualization for histograms or plots is integrated into the system, and the network support for the clients works quite well. A major disadvantage of the interface is its limited flexibility. For example, it is not possible to use more than one window or change/rearrange the items in the window. The input on the clients is limited to sliders, choices or buttons. The complexity of a real-world stock exchange is very high. The functionality of NetLogo – especially the fact that everything must be visualized in one static window – is not sufficient to create complex simulations. In comparison, an advantage of the WIL/MA architecture is that the teacher can make changes during the simulation, stop/pause or continue it, send messages to selected users or modify the value of market parameters (e.g., the exchange rate of the dollar or the oil price). On the other hand, the effort to create a new simulation is higher in comparison to NetLogo. The creation of the client window via drag-and-drop and the visualization of dynamic graphs or histograms are very important features of NetLogo.

In a third simulation based on the WIL/MA architecture, students in a high school studied algorithms for the routing of packets in the Internet. Each participant took the role of a router, received packets and forwarded them to his/her neighbours. The mobile devices were equipped with GPS to get the current geographical position of the participant and WLAN to communicate with the server. The topology of the network depended on the current positions of the students. The simulation was realized in four steps: an introduction, the simulation where the students used PDAs as mobile devices, a discussion, and a questionnaire. A major factor for the learning success was the discussion at the end of the simulation. The motivation of the students was very high and the questionnaire indicated that the complex topic was understood very well.

A major advantage of participatory simulations is the fact that students learn to see patterns and understand coherences much easier. Also, the fact that they become part of the simulated world intensifies their learning experience. At the same time, informal communication and discussion is always an essential part of the learning process. We believe that especially in the case of complex systems under study, the emerging field of participatory simulations can improve the learning success of students significantly.

In summary, our results with interactive lectures show that:

- More than 500 students used and evaluated the WIL/MA system in the last 5 years. The interactive lecture is very well accepted by the students. Comparing the traditional lecture and the interactive lecture within the first 3 years the average acceptance ratings increase from 61,1% to 77,1 % (p=0,001). The questions in Table 2 show the acceptance of interactive lectures.
- There is an increased learning efficacy through the use of the interactive tools. The learning increase measured by a pre/post measurement is higher for students with mobile devices compared to paper-and-pencil quizzes.
- Participatory simulations increase the motivation of the students significantly due to the considerable amount of their own activity.
- We summarize with some positive but also some critical students’ remarks about interactive lectures: “Should be used in more courses.”, “Best lecture of the whole semester, should be repeated and continued, very good.”, “The computers are too distracting to be useful. Even if you don’t use a computer yourself, you feel distracted by other students playing around...”, “I think the concept of interactivity is a very good idea.”, “Computer networks was definitely a lecture of the future, more of that.”

5. Conclusion

Conventional lectures in large classrooms incur a number of serious didactic problems with respect to the cognitive and motivational conditions for learning. The main disadvantage is the limited interactivity between teacher and students and among students. The students' attention, activity and motivation (and, as a consequence, their learning success), as well as the teacher's ability to react to the current mood in the classroom are severely restricted. In order to optimize education in large lectures, we are conducting the LectureLab project. The idea is to support interactions between students and teachers by the use of mobile computers in a wireless network. The students are equipped with handheld computers and use several wireless interactive learning services which provide the possibility of giving feedback in both directions.

Several features seem to be especially relevant when developing a system to support interactivity in lectures:

- The software should be modular and expandable to simplify the extension of the system with new modules. Platform-independent software is necessary because most students want to use their own mobile device.
- The system should support a continuous bi-directional data communication, which means that the data is transferred from students to the teacher and back. In addition, different aggregation levels are relevant, which enable the communication between individual students, groups or all users.
- The scalability of the system is very important. It should work in small classes with 20 students, but also in large lecture halls with 150 or more participants. Data abstraction and data aggregation methods are important to support the teacher.

The experimental field studies show that a large interactive lecture involving the use of mobile computers significantly strengthens the learning process in higher education. Wireless networks, together with an appropriate didactic concept, are a new and promising possibility to actively integrate the students into the process of learning. Apart from promoting the attention and motivation of students, a key point is that this scenario also improves the learners' knowledge acquisition.

We conclude with some recommendations based on our experiences gained in the last five yeas with interactive lectures:

- Interactive lectures are especially useful for tele-lectures or large lectures. The benefit compared to the additional effort is relatively small for lectures with 20 or 30 students.
- The mental load in interactive lectures is very high for the teacher. Not only the topic of the lecture is relevant, but the teacher also has to concentrate on many different input sources like questions, feedback and quiz results. The mental overload is reduced significantly if a second person handles the technical stuff and answers or filters questions.
- The lifetime of the battery of mobile devices is very short (less than 2 hours), especially if wireless LAN is used. It is important that sufficient time is available between two interactive lectures to recharge the devices.
- The interactive software should support the teacher and keep the additional effort to prepare the interactive lectures as low as possible. A comfortable interface to create questions is an important step.

- Feedback of the students should be preserved and reused. For example, we create a FAQ list with all questions and answers, which is available for students in the following years.
- The interface of the interactive learning software should support the devices of the students in an efficient way. Text input is only useful if notebooks are used. Small devices have a great advantage in classes with small tables, but the interface should generally use drawing or clicking.
- It is important to support standardized technology because students prefer to use their own devices. Specialized hardware or software usually prevents the usage of the system by other people and is usually much more expensive.
- Early trials with the new tools are recommended; they lead to very valuable insights.

For a long term into the future, lectures in large classrooms will not become obsolete in higher education for cost reasons. Thus, an enrichment of this teaching method around interactive and adaptive elements will be a persistent optimization. Using the technology to transform traditional lectures into interactive lectures is possible in all educational institutions as long as the learning content can be mediated in lecture methods. Because of the flexible application of the hard- and software as well as the adaptive didactic concepts, no structural changes in the educational system are necessary. By an immediate integration of interactive lectures in different disciplines, presence teaching can be strengthened by the creation of an individual flexible model. By means of an interactive lecture, it is possible to integrate new media into higher education directly in a didactically meaningful and economical fashion.

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