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# The MUNIN Teleteaching System

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**Abstract**

«Distributed Electronic Classrooms» are used for for lectures, meetings and seminars with equal participation from two or more sites. Distributed Electronic Classrooms are equipped with audio and video technology as well as an electronic whiteboard used to link classrooms over the Internet or ISDN. This technology has been under development since the early 1990's and in usage for full-semester lecture series between Norwegian institutions of higher education since 1993. The system is currently being extended to include participation from workstaions and recording and playback of lectures using networked digital servers. This paper give an overview of the system, the current deployment and usage as well as a summary of some of the findings from evaluations of the system.

The Distributed Electronic Classroom system has been developed by the Center for Information Technology Services at the University of Oslo in collaboration with Telenor Research and the University Studies at Kjeller. The project has received support from the Norwegian Ministry of Education, UNINETT and Hewlett-Packard.

**Keywords**

Distributed Electronic Classrooms, Internet, IP Multicast, ISDN, H.261, Real Time Transport Protocol, World Wide Web, Distance education

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## 1 The background for the MUNIN-project

The original inspiration for starting the MUNIN-project came from two sources in the early 1990's. At that time the Norwegian government started to formulate a new policy for the organisation of colleges of higher education. Based on this policy what used to be more than 100 colleges have been reorganised into 26 regional colleges for higher education. The colleges are in a process to develop their individual characteristics with respect to courses offered and to establish mechanisms to allow students to combine courses from more than one colleges as part of their education. The reorganisation of the schools for higher education has not resulted in a relocation of the old colleges and as a consequence most of the colleges are distributed with several campuses throughout a region of the country. Because of this the colleges have identified an immediate need for tools to conduct meetings and distance education between the campuses. To support the reorganisation process the government is providing extra funds to the colleges to upgrade their telecommunication infrastructure.The four Norwegian universities are not directly affected by the reorganisation of the colleges for higher education.

Also in the early 1990's Telenor, the Royal Ministry of Education and UNINETT A/S agreed to establish an experimental high speed IP network connecting the Norwegian universities as well as Telenor Research. It seemed clear to us at that time that this infrastructure would be able to support real time communication of video and audio.The network - named Supernett - operates at 34 Mbit/s and was during fall 1995 upgraded to ATM technology as well as expanded to more sites.

A desire to provide technology for better cooperation between the universities as well as to support cooperation between and within the colleges for higher education and the availability of Supernett was the starting point for the MUNIN-project.

## 2 Design goals for the MUNIN-system

Through the MUNIN-project we wanted to develop a system which allowed teachers and studentes who are located at different sites to participate in the same class without a need to change the structure of the learning process as known from the traditional classroom. The usage scenarios which we in particular want to support are:

- Lecturing in small to medium sized groups.
- Tutoring in small to medium sized groups. The main difference between lecturing and tutoring was viewed to be a higher degree of interaction during tutoring.
- Formal and informal meetings.

It has been a significant design consideration that the system shall be a tool that can be used by most lectureres and students without much training in how to use the system. The system must be easy to start using and easy to use.

To ensure a low threshold for starting to use the system, it was decided that it should be centered around the traditional classroom. As a long term goal it should allow students to join in partially or fully from workstations in a way which put less demand on the infrastructure and on the terminal equipment compared to participating from classrooms. Participation from workstations could be both for usage on campus and for usage by people attending a course from his or hers workplace as part of continued education. To allow the greatest possible integration with other information technology tools, the system should be based on Internet technology. In particular the system should be integrated with the World Wide Web (WWW). This both to be able to draw on the wealth of information available now and in the future on the WWW, but also because information produced for usage in this system can easily be made available for other usages.

The system should allow for recording and playback of lectures. This should be done in such a way that students are able to play back lectures into classrooms and to workstations. The system should also to some degree be integrated with the ISDN H.320 based video conferencing world allowing a limited form of communication with ISDN video phones and video conferencing systems.

Last but not least, the system should support teacheres in improving the quality of his/her teaching.

## 3 Distributed Electronic Classrooms

Based on the above design goals the project has developed the distributed electronic classroom as an augmentation of the traditional classroom. A distributed electronic classroom (or electronic classroom for short) contains a number of technological components to allow for linkage to other electronic classrooms.

Three channels are used to link classrooms: audio, video and an electronic whiteboard.

- For audio emphasis has been placed on high quality, i.e. high audio bandwidth and full duplex.
- The shared electronic whiteboard fill the role of the traditional whiteboard as well as the role of the over-head-projector. The whiteboard can be written on using a special pen and the teacher can also bring up any page from the WWW and annotate on the page.
- The video is used as a supporting medium to audio and the electronic whiteboard and is an important medium for creating social contact between the participants in the classrooms involved.

An important part of the design is how the technology is integrated into the classroom. A guideline to this part of the design has been a desire to hide the technology by integrating it into the classroom and making the usage of the technology to communicate a natural extention of how the users would have communicated had they all been in the same classroom.

Microphones are placed in the ceiling so that the users does not have to operate them and the users can be anywhere in the room and ask questions and participate in discussions. The teacher either use a wireless lavaliere microphone or is covered by the ceiling mounted microphones.

The leadspeakers are also mounted in the ceiling, in the area separating the first row of students and the teachers podium. (This is not shown on the figure below.) This is done in order to give the students the impression that the sound from the remote classroom is coming from the front of the local classroom, thereby directing their attention in that direction. Likewise for the teacher it appears that the audio is coming from the area of the room where the students are, directing his attention in that direction.

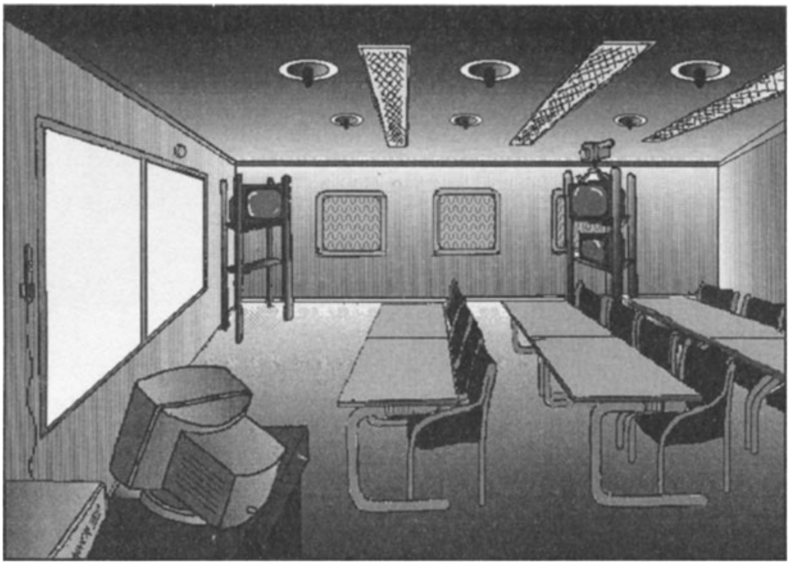

Figure 1: An electronic classroom

In each classroom there are two cameras. One in back of the classroom on top of a rack with two monitors and one in the front of the room directly above the back-projection board to the right. Which one of the two cameras that is active is automatically determined by the system based on where in the classroom sound is being made, i.e. where the speaker is located. Directly below the camera on the rack in the back of the classroom there is a monitor showing incoming video from one of the remote classrooms. This close co-location of camera and monitor create an impression of eye-contact, and is important for creating social contact between the participants. The bottom monitor in this rack is a self-view monitor which at all times show the video picture being sent from the local classroom. The rack in the back of the classroom is being used only by the teacher.

In the front of the classroom where the blackboard is usually found there are two semitransparent boards mounted in the wall separating the electronic classroom from an adjoining room. Behind each board is a video-projector. The board to the left is the electronic whiteboard and the board to the right show video from one of the remote electronic classrooms. This is at all times the same video picture being shown on the top-most monitor on the rack in the back of the classroom. Again the close co-location of the video camera and the video-projected image from a remote classroom is supporting social contact.

Figure 2: The Electronic Classroom at the University of Bergen

Control of each electronic classroom is done through the teachers console. This is an X-terminal with a touch sensitive coating on the screen allowing the teacher to control most aspects of the electronic classroom by pressing buttons on the screen. The teacher (or a student) can also use the teachers console to instruct a colour scanner in each classroom to scan information from print onto the electronic whiteboard.

The electronic whiteboard is a shared workspace application which is controlled by a pen-based interface and through the teachers console. The teacher can write by hand on the whiteboard with a special pen just like he would have written on an ordinary whiteboard. The participating electronic whiteboards are connected through shared workspace technology so that what is written on one whiteboard is immediately also shown on the electronic whiteboard in the other participating electronic classrooms. Through the teachers console pages from the World Wide Web can be brought onto the electronic whiteboard and the user can annotate on the pages. In the future teachers will be able to preview pages for the electronic whiteboard graphically on the teachers console.

The protocols forming the basis for the electronic whiteboard is developed by the project and based on IP Multicast. Above IP Multicast is a reliable transport protocol providing a stream service whereby each participant is able to send to all other participants. Above the reliable transport layer is a generic shared object oriented database called «Shared Objects». Shared Objects is implemented in C++ and structured so that the user may by subclassing create application specific objects shared between applications. On startup an application will use multicasting to locate the nearest participant in the desired conference and then transfer the current state of the shared database from that partner using a combination of tcp/ip. For the electronic whiteboard a set of objects representing whiteboard pages and the graphical components on the pages have been defined as subclasses of the generic Shared Object objects. The whiteboard application is based on these objects.

The gateway from World Wide Web to the electronic whiteboard has been implemented using the World Wide Web Consortium Reference Library implementation for retrieving and interpreting Web-pages. The above mentioned shared objects are used by the gateway for creating and drawing on pages on the electronic whiteboard.

As can been seen from the figure below, the user interface of the electronic whiteboard consists of a tool-bar to the left and a large drawing area to the right. The tool-bar let the user select a drawing tool, and attributes to the drawing tool like pen colour, fill colour and pen width. Also, the user can write on the electronic whiteboard using a keyboard, erase from the whiteboard and follow Web-links. Pages on the whiteboard can be taller than the physical height of the electronic whiteboard, and the whiteboard is therefore equipped with a scroll-bar.

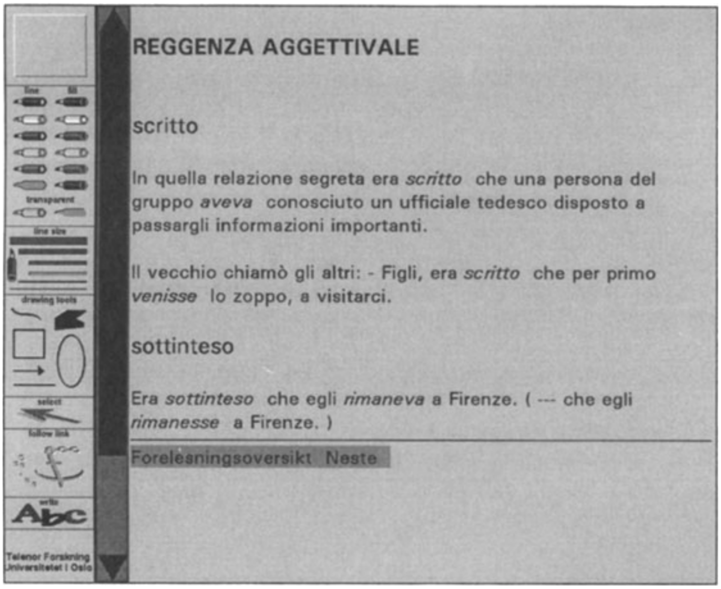


Figure 3: Screen dump of the electronic whiteboard showing a Web-page used in a course in Italian language syntax.

The project has chosen to design electronic classrooms around an Hewlett-Packard Unix computer. Units being part of the system is either connected to this computer over a serial line, through the parallell port, through the SCSI-interface or through (E)ISA cards inserted into the machine.

Communication between electronic classrooms take place over the Internet using Internet standards where available. One reason for chosing the Internet as a basis has been to make integration with workstations as described below feasible.

Up until now electronic classrooms have only been used for linking together pairs of classrooms. The software has over time been developed from being based on Internet unicast to multicast technology. For some time the electronic whiteboard has been based exclusivly on multicast technology while the audio and video software has been able to utilise both multicast and unicast. Now, also a session control protocol supporting more than two participating classrooms has been implemented and will allow us to start gaining practical experience with conducting sessions with more than two participating electronic classrooms.

For video an H.261 variable bitrate codec is used. The codec is in the form of an ISA-card produced by Bitfield OY. The MUNIN-project has in collaboration with Bitfield produced an HP Unix driver for this card. The network bandwidth used for video is typically in the range from 500 to 1.500 kbit/s although the codec is able to code and decode at any rate from 8 kbit/s up to 2048 kbit/s. When electronic classrooms are connected over the Supernett audio is transfered using 16 bit linear samples at 16 khz giving an excellent audio quality but resulting in a datarate of above 256 kbit/s. When bandwidth is scarce a compression is used, e.g. 16 khz PCM.

Both audio and video is communicated over the Internet using version 1 of the the Real Time Transport Protocol . This protocol is now obsoluted by version 2 of the same protocol which published as RFC 1889 as a Proposed Standard Protocol in January 1996.

## 4 Participation from workstations

The design of the MUNIN-system include the ability for students to participate either actively or passively in lectures from work stations. Both the audio and video quality as well as the functionality of the electronic whiteboard will be degraded compared to an electronic classroom, and the user may choose only to participate through some of the medias, e.g. only by audio and the electronic whiteboard.

There are currently a number of applications generaly available for conducting video conferencing over the Internet. Many of these applications are in conformance with the existing and emerging standards for Internet video conferencing. [Kirstein 1995] Both the audio and video streams in the MUNIN-system are conformant to the same Internet-standards, but as the datarates used between classrooms is high in order to achieve a good quality, it can not be decoded by the software decoders used on workstations. Also, the bandwidth used is too high for making these datastreams widely available on the net. The MUNIN-project is not developing any new applications for users of workstations to take part in MUNIN-sessions, but are creating software acting as a gateway between users of Internet videoconferencing software and the electronic classrooms.

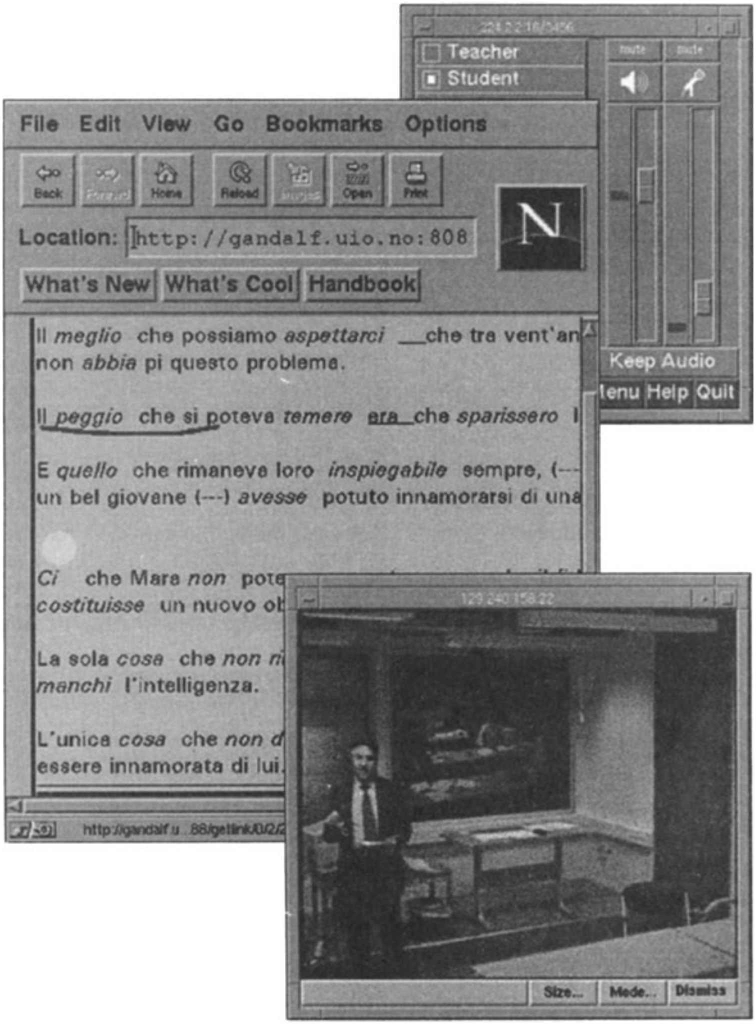


Figure 4: Screen dump from the Unix workstation of a user watching a lecture taking place in an electronic classroom. Audio and video is received through the Unix conferencing applications vat and vic, and the electronic whiteboard as a WWW-page through Netscape.

For the electronic whiteboard, a gateway has been made to World Wide Web in such a way that users access a specific URL to view the electronic whiteboard. Updates to the whiteboard is automatically fetched by the users WWW-client at small intervals.

The teacher will in the future be able to control whether workstations are allowed to participate through the teachers console.

## 5 Recording av playback of lectures

Through other projects including the ESPRIT MICE-project an Internet real time media server which is able to record and play back real time media streams on the Internet has been developed. The media server implementation is partly based on software developed by Anders Klemets at KTH [Klemets 1994]. The server is compatible with applications currently being used for video conferencing on the Internet and the protocols used for audio and video between the electronic classrooms.

The media server is implemented as a set of programs on a Unix server. The recordings are stored as a series of files on an optical jukebox. During playback files are brought onto a harddisk from the jukebox on an on-demand basis. Control of the server is through a program interfaced to the Web through the Common Gateway Interface (CGI) (See http://hoohoo.ncsa.uiuc.edu/cgi/intro.html for information on CGI.). Playback of the medias is synchronised in time and the user can pause the playback and jump forwards and backwards as he pleases.

The teacher will in the future be able to control recording and play back to classrooms from the teachers console. Play back to classrooms will be both to a single classroom and playback into a conference, e.g. to review material from a previous lecture. Users of workstations are able to control playback of audio and video recordings through the World Wide Web. An example of a Web-page to control the play back of a recording is shown below.

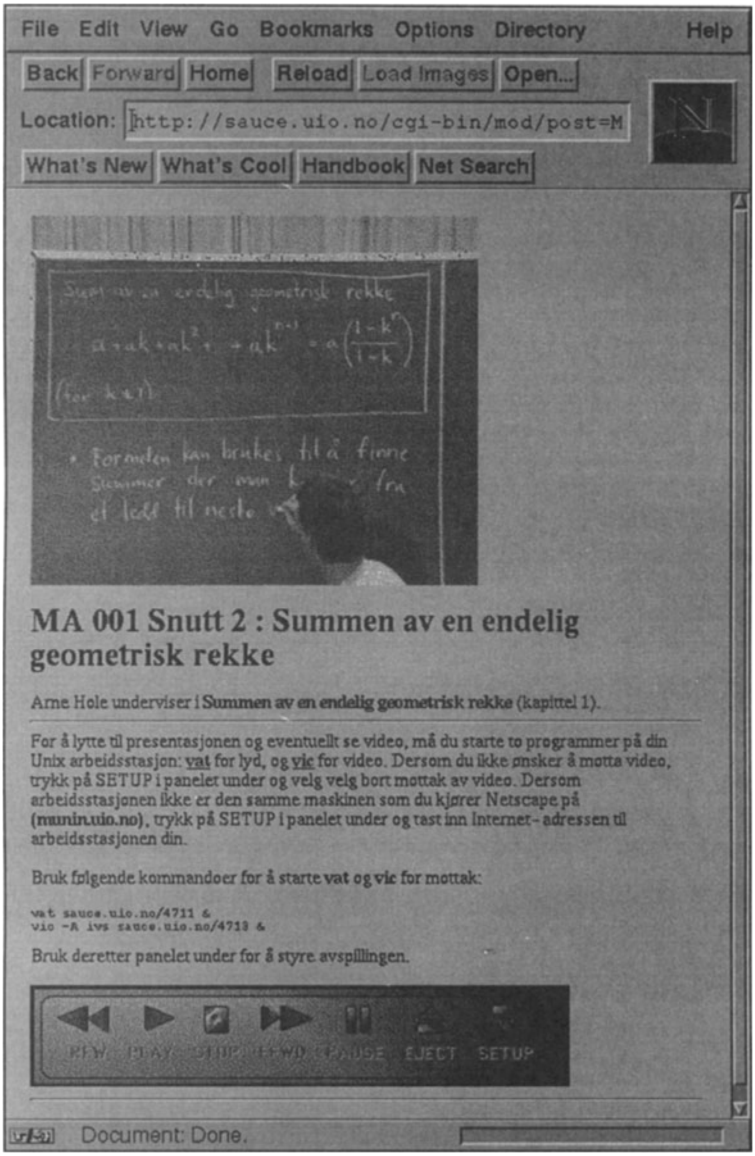


Figure 5: Web-page for controlling playback from the real time media server. For users outside of Norway, the instructions are in English language.

## 6 Electronic Classrooms as multipurpose rooms

Establishing an electronic classroom will currently for most institutions be a considerable investment. Many organisations will be able to utilise some existing equipment to bring the cost down. Because of this, it is important that an electronic classroom has a wide range of applications, and electronic classrooms are often viewed as multi-purpose rooms.

In addition to its usage for distance education and video conferencing with other electronic classrooms, electronic classrooms are often used for:

- Computer supported teaching where the teacher is demonstrating or using software as a part of his teaching. In this mode the electronic whiteboard is simply projecting the image from the X-console of the classroom computer.
- ISDN videoconferencing. As the videosystem part of the electronic classroom is compatible with the H.320 ISDN videoconferencing standard, it is possible to use the existing system as an ISDN videoconference system by adding an inexpensive ISDN card.
- For viewing video or television broadcasts. For this purpose as well as for recording lectureres on ordinary video tape, electronic classrooms contain a video player.
- Last, but not least the electronic classroom can be used as an ordinary classroom. For many institutions where rooms are scarce it is important that the room selected to be used as an electronic classroom is not lost as an ordinary classroom. Some institutions have chosen to install an ordinary whiteboard or blackboard in front of the back-projection boards so that they can be slided up or sidewise when the room is used as an electronic classroom.

## 7 Current deployment and usage of the MUNIN-system

The firt two electronic classrooms was established during spring and summer of 1993 at the University of Oslo and at the University Studies at Kjeller (UNIK). UNIK is situated some 30 kilometers outside of Oslo on the same research campus where Telenor Research is located. These two classrooms have been used for teaching full semester courses each semester since the fall 1993 semester. Some parts of the technical installation in the classrooms have been updated during this period to improve stability and quality, but the basic setup has remained mostly unchanged.

During the summer of 1994 a third electronic classroom was built by the University of Oslo at the University of Bergen (UiB) specifically for use by the Faculty of Arts. This electronic classroom was fincanced by UiB. Since the fall 1994 semester courses in French and Italian language and culture has been given between the electronic classrooms at the University of Bergen and University of Oslo. The participants from the Faculty of Arts at the University of Oslo has in this period been using the electronic classroom at the Center for Information Technology Services. This classroom is located some distance away from the location of the

Arts faculty and is used as a laboratory by the MUNIN-project. Work is currently in progress to initiate the establishment of a separate electronic classroom at the Faculty of Arts at the University of Oslo.

The courses which have been given between UNIK and the University of Oslo has been aimed at graduate informatics students which are well accustomed to the usage of technology. The participants in the courses given between Oslo and Bergen has been undergraduate and graduate students at the Faculty of Arts. Most of these students do not regularly use computers.

Currently there is one technican present during all lectures in electronic classrooms, but the system is being developed with the aim of elimenating the need for this.

Work is currently under way at four to five other norwegian universities and colleges of higher education to investigate the feasibility or finance establishment of electronic classrooms.

In addition to the usage of the electronic classrooms for courses, the classrooms has been used for regular and sporadic meetings since their establishment.

## 8 The KOMPAKT videoconferencing system

For video-conferencing between campuses part of colleges for higher education, a scaled down version of the electronic classroom has been developed. This has been done as part of the KOMPAKT-project which has as its general aim to improve the telecommunication services for the reorganised colleges. The KOMPAKT-project is funded by the Ministry of Education and executed by UNINETT.

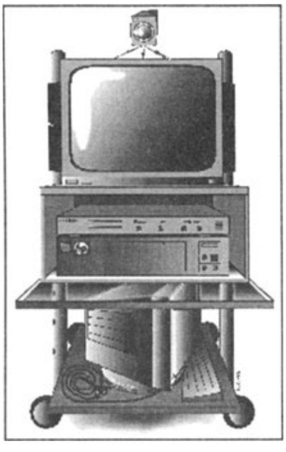

Figure 6: The KOMPAKT videoconferencing system

The KOMPAKT video conferencing system consists of the video and audio parts of the MUNIN-system installed in a rack which can be moved between different locations at one site.

The system is usually equiped with three microphones making it suitable for five to eight participants at each site. As part of the KOMPAKT-project the system has been extended to support ISDN videoconferencing. The KOMPAKT videoconferencing system is both a 6B-channel ISDN videoconferencing system and an Internet video conferencing system. In most installations the system is also configured as a campus MBONE-router and in some places also serves as a CU-SeeMe reflector.

Currently there are five installations of the KOMPAKT video-conferencing system. Three at campuses of Telemark College, one at Nord-Trøndelag College and one at the offices of UNINETT. These systems are being used regularly for meetings of vairous types within the colleges.

## 9 User feedback and evaluation

The considerable number of courses given through the MUNIN-system since its first usage in 1993 has provided a basis for collecting much information from users on the strengths and weaknesses of the system. Questionares and group interviews has been used as a basis for several formal and informal evaluations. Telenor Research has published one evaluation report [Jensen 1995]. An evaluation project funded by Norwegian Executive Board for Distance Education at University and College Level (SOFF) has produced one report [Rydning 1995] and a masters thesis discussing how the technological equipment influences the communication between users of electronic classrooms has been written [Eidhamar 1995].

### 9.1 Evaluation by Telenor Research

The main conclusions from the evaluation report by Telenor [Jensen 1995] will now be pharaprased. Two lectures of the same course by the same teacher form the basis for this report. The courses was given during the fall 1993 and fall 1994 semesters and was on computer networks aimed at graduate computer science students both at the Institute of Informatics at the University of Oslo and at UNIK. The courses involved two linked classrooms using a first version of the electronic whiteboard which was not linked with WWW and had fewer drawing options than the current electronic whiteboard. The teacher gave the course from the electronic classroom at UNIK.

The report concludes that the electronic classroom satisfies basic pedagogical requirements for conducting distributed teaching. However, the leacturing in the courses that was evaluated suffered under instability problems of the technology used and also by certain organisational weaknesses. How the students judged the technology depended somewhat on where they was located with respect to the location of the teacher with the distant students being more positive than the local students.

For the teacher, the initial change to the use of this system was significant, but both the teacher and students report that they fast gained a familiarity with the system. The technology influenced how both teachers and students behaved during class. The teacher reports talking more slowly and pronounced than he would have in a traditional classroom, while students report that they became more aware of their behaviour in the classroom, e.g. by being more quiet during class. The teacher felt that activating the students was the greatst problem he faced due to the system. This was the case both for local and remote students, but more for the remote students. Two suggestions as to how this may be overcome is provided:

- The remote students and teacher should meet before the start of the course.
- The students should be allowed to train on the usage of the technology or in some other way gain experience with being exposed through the system.

The report concludes that the electronic whiteboard without doubt make it easier for the distant students to follow the lecture. The remote students was very much satisfied by having the ability to interact with the teacher, even though such interaction seldom occured.

## 9.2 Some issues of importance for the success of the MUNIN-system

How successfully the electronic classroom has been conceived by the users have to a great extent depended upon the qualitites of the components part of the system. In this section we will present a summary discussing qualitative requirements for some of the components part of the electronic classroom system. Through the evaluations it has been confirmed that the total design is satisfactory.

For audio it is important that all participants can hear each other at all times and that the audio is full duplex. The transport delay for audio must not be above a certan limit or else this will cause the interactivity in the oral communication to break down. Users should be able to recognise other participants based on voice.

For video it is important that the students are able to see the face of the teacher as well as his body language. The teacher need to get an overview of the students, and is to a lesser extent dependant on video being focused on particular students. The video medium is very important for creating social contact between the participants at different locations. A large projected video image results in subjectivly better social contact between the classrooms, and ensures that more students can see the teacher clearly. The frame rate for the video should not be much below that of ordinary video.

When using the electronic whiteboard to write by hand, it is important for the teacher that the system is able to receive and communicate fast handwriting. There should be an electronic pointer allowing the teacher to point at the electronic whiteboard from a distance away from the board. For the teacher it is important that production of foils is easy, either on a computer or by hand. It is of importance that the electronic whiteboard has the right functionality. A missing feature remarked by the teachers is functionality for gradually revealing the contents of a page. Bringing a foil onto the whiteboard should not take more than a few seconds. The teachers need a way to easy navigate amongst prepared pages - a role that will be filled by the teachers console.

Generally stability is extremely important. This system is partialy replacing existing teaching equipment like the over-head-projector and the whiteboard. The users need a stability of the total system approaching that of these traditional tools.

For student satisfaction, the quality of the air in the electronic classroom is important and should not be perceived as hot and dozy.

For the teachers, conducting a lecture in the electronic classroom require more preparation than conducting the same lecture in an ordinary classroom. This is mostly because creating the pages for the electronic whiteboard still take more time than creating ordinary foils for over-head-projectors. The teachers also report that teaching through the electronic classroom is more demanding than ordinary teaching. This as the teacher will to some degree have to be conscious that there are more than one group of students involved and that the teacher have to operate more technology than he has traditionally been doing. However, the teachers report that it is easy to start using the system. Teachers has received as little as 1 to 2 hours of training before successfully conducting a full-semester lecture series via the electronic classroom.

There is an observed tendency that students participating in courses given through electronic classrooms are more passive than students attending other courses. The students also to some degree rate themself as more passive. The marks received by students participating in courses through electronic classrooms are no different than marks received by students in similar courses not given through this technology. Students who have followed courses given through electronic classrooms in general report at the end of the course that they have a positive attitude towards participating in future courses given through the system. Questionares collected during the fall 1995 semster show that the students from the Faculty of Arts was more positive to attending classes in the electronic classroom after having completed a course in the classroom than they were at the start of the course.

## 10 Conclusions

This paper has presented an overview of the MUNIN-project which have developed a Distrubuted Electronic Classroom system for distributed education, meetings and seminars. The system is today in regular usage between three university campuses in Norway and a reduced system has been deployed at an additional five sites at Norwegian colleges for higer education. A number of universities and colleges of higher education are at this time investigating establishing electronic classrooms. Hedemark College has recently decided to establish an electronic classroom at Rena and it is expected this installation will be completed by the end of April 1996.

Evaluation of the system has shown the electronic classrooms are suited for distributed teaching. However, the quality and stability requirements for such a system to be usable are high and the system can still be improved in this area. Both students and teachers are generally satisfied with the system, and find the system easy to start using and easy to use.

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