Evaluation of Tele-tutorial Support in a Remote Programming Laboratory

Andreas Böhne, Klaus Rütters, Bernardo Wagner

Learning Lab Lower Saxony (L3S), Hanover, Germany
{boehne, ruetters, wagner}@learninglab.de

Abstract

Laboratories allow students to apply their theoretical knowledge in a situated context. Many students only work and learn successfully in such a complex laboratory setting when they get instructional support from a human tutor. This support is provided by a local tutor in classical local laboratories. To provide such support in a remote lab as well, we developed a web based lab environment, which supports synchronous tele-tutorial assistance by a human tutor. To evaluate synchronous tele-tutorial support we conducted a controlled experiment with 19 electrical engineering students. The students worked in groups of two or three on a remote programming experiment, while a tutor assisted them with the synchronous communication tools video conference, text chat and desktop sharing. Regarding this lab setting, our research questions were: Has synchronous tele-tutorial support the potential to provide a high quality of instructional support? Which communication media are most useful for such a lab setting? Does self-directed as opposed to teacher-directed learning lead to better task successes and student motivation? Therefore, all student groups were remotely assisted by a human tutor and either exposed to a self-directed or a teacher-directed setting. We measured students' initial knowledge, use of the different communication media, consulting effort, contentedness with tele-tutorial support and students' motivation, and analyzed task success. The results of our study show that the students were content with the remote tele-tutorial support. Students rated audio chat and desktop sharing as most useful and video picture of the tutor and text chat as less important. Contrary to our expectations there was no statistically significant difference between the motivation and the task success of students working in the self-directed setting and students working in the teacher-directed setting.

Introduction

A major goal in engineering education is that students acquire problem solving and creativity strategies so that they become able to construct technical systems. Such strategies can be learned by working on small problems and construction assignments in a problem-based learning environment. Laboratories are a typical example of a problem based learning setting. They allow applying and testing theoretical knowledge in practical learning situations, in which students have to solve complex problem solving tasks. But without instructional support such complex tasks will often demand too much from the students and will lead to ineffective learning[1,10]. Therefore, in typical local laboratories, students can get assistance from a local human tutor. We think that in a remote laboratory a tele-tutor, who can communicate by synchronous communications tools with the students, is a solution for instructional support that meets the special requirements of a remote laboratory (learning independent from time and place) and that can also be effective with regard to the learning results.

In contrast to local laboratories, remote laboratories allow students to learn independent from time and place. This flexibility should also remain when providing instructional support in remote labs. But there is a conflict of interests between keeping this flexibility and providing a good quality of instructional support (see figure 1): The highest flexibility regarding time and place is available for students, when they do not get instructional support by a remote human tutor. And the highest level of instructional support can be achieved by a local human tutor who is in the same room with the students. But in this case the students have no flexibility in choosing their learning time and place. Compared with a traditional local lab with local tutor, the geographic proximity restriction is only removed regarding the place of the experiment.

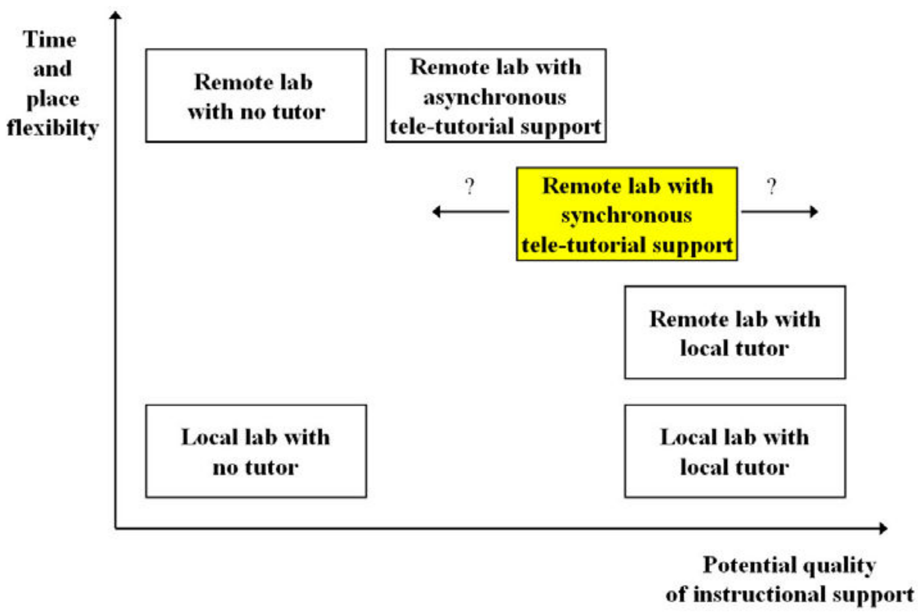

Figure 1: Local and Remote Labs: Time and place flexibility vs. quality of instructional support

On the other hand, the solution to provide no instructional support by a human tutor can have far reaching consequences for the motivation and the learning results of students, who learn with a remote lab. Geyken et al.[5] have analyzed the learning process, learning motivation and learning results of adults, who learned with a CBT and a problem based learning environment, comparing two groups: One group had the possibility to contact a remote tutor via audio conference and desktop sharing. The other group had to learn with no tele-tutorial support. The results of this field study show that tele tutorial assistance can lead to:

- a higher acceptance of a computer based learning environment,
- better learning results,

- a better transfer of the acquired knowledge to practical situations
- and a higher motivation.

Geyken et al. emphasize the importance of a remote in tutor especially in situations, when learners have problems and questions. Without the possibility to get an immediate feedback by a remote tutor many learners became demotivated and aborted their learning.

Therefore, we decided to implement and evaluate a remote lab setting with synchronous tele-tutorial support. In such a lab setting, the tutor needs not to be in the same room with the students. He can assist the students from all over the world, when they work with an experiment that also can be located at another place. Of course, flexibility in choosing learning time and place and a good quality of instructional support are not the only important criteria for the decision, how to implement a remote lab setting. The personnel costs for a human tutor also can be a relevant factor in the decision process. But one has to consider that reducing the personnel budget for a remote lab by providing no instructional support by a human tutor, can lead to ineffective learning in a remote lab. Especially, when the students have to solve complex problem solving tasks in the remote lab, learning should take place in a social context. If students have experts as models they can acquire skills, knowledge and orientation[10]. Furthermore the efficiency of synchronous tele-tutorial support can be increased, when the remote tutor supports more than one lab group at the same time. In the study described in this paper the tutor only assisted one student group at the same time, because the research focus of the study was the effectiveness and not the efficiency of remote tele-tutorial support.

Research Questions

CSCW research has already analyzed on how specific CSCW environments affect different aspects of distributed work, e.g. task performance, social pressure, social presence, awareness, trust and group identity. For example, Kiesler[6] emphasized the absence of social cues in text-based communication. Mark et al.[7] reported the benefits from desktop sharing for distributed working groups. Sonnenwald[11] found no statistically significance difference between task performance of distributed and collocated groups, when scientists had to work on an experiment task. But a remote experiment, where students are assisted by synchronous tele-tutorial support, is a distributed computer supported collaborative *learning* setting with certain characteristics[12]:

- Pedagogical concept: In most laboratories, students have to solve complex tasks in a situated context, so the pedagogical concept is problem based learning.
- Synchronous learning: Synchronous support is used, when the students work with the lab equipment. For the preparation and postprocessing of the laboratory session they can interact via asynchronous tools like E-mail.
- Asymmetric learning: The tutor has more knowledge than the students.
- Group size: The tutor supports only small groups of students during the execution of the lab.
- Duration: Students work only few hours on a typical remote experiment.

How effective synchronous tele-tutorial support can be in such a specific CSCL setting, is one of our research interests. In the study described in this paper, our specific research questions regarding the instructional quality of tele-tutorial support in remote laboratory were: Are students content with tele-tutorial support? Or do they miss a local tutor?

Furthermore, we wanted to evaluate a certain mix of synchronous communication tools. In our remote experiment students' groups and tutor were able to communicate and collaborate via video chat, desktop sharing and text chat. Which of these tools are useful in a remote laboratory with synchronous tele-tutorial support, was another research question in our study. We hypothesized, that the video chat will be more important than the text chat, because it allows an immediate feedback without the need of good typing capabilities. We also expected that desktop sharing would be important, because desktop sharing is an effective way of synchronous information exchange. It allows a smooth collaboration of distributed teams by providing shared references in colour with high resolution[7].

Besides these research questions, we were interested on the effects of different instructional methods in a remote laboratory with tele-tutorial assistance: Is self-directed or teacher-directed learning more suitable for a remote laboratory with tele-tutorial assistance? Self-directed learning seeks to put the learner as much as possible in control of the learning process. The freedom of choice can refer to different dimensions like learning goals, learning place and time and learning strategy[2]. Regarding the degree of self-directed learning we have implemented two different educational settings:

- Self-directed. High degree of self-direction of the students considering learning goals, tasks, problem solving process and tutor role. The tutor acts as an e-coach or e-moderator. He supports the students in learning to learn, moderates the group discussions and answers the emerging questions of the students.
- Teacher-directed. Low degree of self-direction considering learning goals, tasks, problem solving process and tutor role. The tutor acts as an e-instructor: He explains the tasks, guides the group in the learning process along the structure of the subject rather than the actual task (i.e. subject-oriented) and answers the questions in a subject-oriented way.

Based on the "Self-Determination Theory" (SDT) of Deci, Ryan[4] we expected that the students in the self-directed setting will be higher motivated and get better learning results. Deci, Ryan posit that competence, relatedness and autonomy are basic psychological needs of each human being. Following SDT, the satisfaction of these needs supports self-determined types of motivation. Deci, Ryan distinguish amotivation, forms of extrinsic motivation and intrinsic motivation on a continuum of self-determination. When students perceive a high support for competence, social relatedness and autonomy, according to Deci, Ryan a more self-determined type of motivation can be developed and so better learning results can be achieved. Different studies have confirmed these hypotheses in an educational context[8,9].

The experiment as context of the study

We have developed a remote experiment for picture generation by laser deflection[1]. In this experiment, students write embedded Java programs to generate laser pictures and animations. The laser system of the experiment consists of a green 3mW laser beam, which is deflected by two mirrors of a galvanometer scanner in X- and Y-direction (see figure 2). The scanner can move the beam to 30,000 positions per second. The deflection is controlled by two analogue inputs of the scanner. They are driven by DA-converters controlled by an I/O-Card in an embedded system. The galvanometer scanner and the laser can be turned on and off by the digital outputs of the I/O-Card. An analogue input of the I/O-Card measures the voltage signal of a photosensor that is placed on the canvas. When the laser beam hits this sensor, the voltage output of the sensor increases.

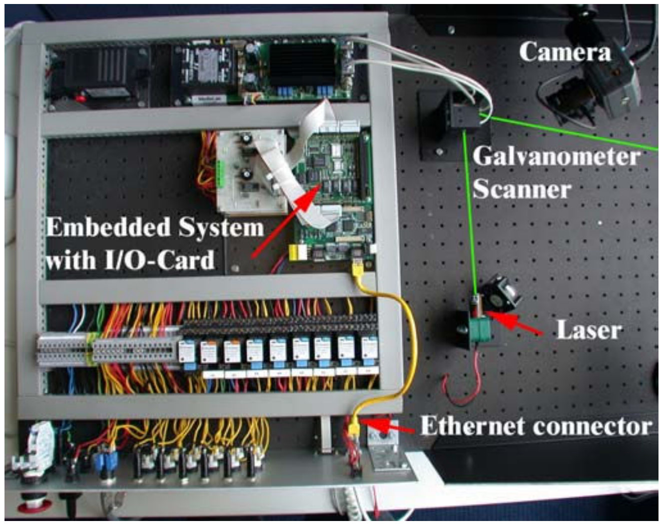

Figure 2: Laserexperiment components

Students generate pictures by developing embedded Java programs in a web based programming environment (figure 3, middle part). It allows editing of Java program files in the editor window. Files can be loaded and saved on the lab server of the experiment with the buttons and input fields on the upper left. The upper right of the programming environment is for compiling and running Java programs. Java files are compiled on the lab server (button "compile") and compiler messages are displayed in a separate window. To start a Java method on the embedded system, the user asks for a list of Java methods in the file ("inspect"), chooses a method ("select"), enters actual parameters in a separate window and calls the method ("start"). If the program works correctly, the laser system will generate a picture on the canvas. A separate console output window facilitates the debugging of Java programs.

The left part of the window in figure 3 allows students remote access to the lab and is thus a substitute for being present in the lab ("telepresence"). They can select among three fixed cameras to see a live video of the canvas, the status lights of the devices or the moving galvanometer scanner and one camera ("PTZ-Cam") that allows users to pan, tilt and zoom in on details. Users can switch on and off the embedded system.

The right part of the window in figure 3 provides the possibility for different users to communicate with each other over a distance. They can communicate via audio, video and text chat after logging in with a username. The bandwidth can be adapted to the available bandwidth. The client side of the communication environment was realized with "Macromedia Flash MX". The communication server is based on the "Macromedia Flash Communication Server MX". Desktop sharing is provided by an external tool. We used VNC (http://realvnc.com) for this purpose. VNC is platform independent, but only allows complete desktop sharing and not to share only a certain application or browser window.

Instead of the operating mode "Programming" shown in figure 3, the user can select the modes "Manual Control" or "Dynamic Test". In the "Manual Control" operating mode the user can deflect the laser beam by two sliders or text input fields in X- and Y-direction. Furthermore the current voltage output of the photosensor and the status of the window discriminator are displayed. In the mode "Dynamic test" the users can measure the dynamic characteristic of the laser system.

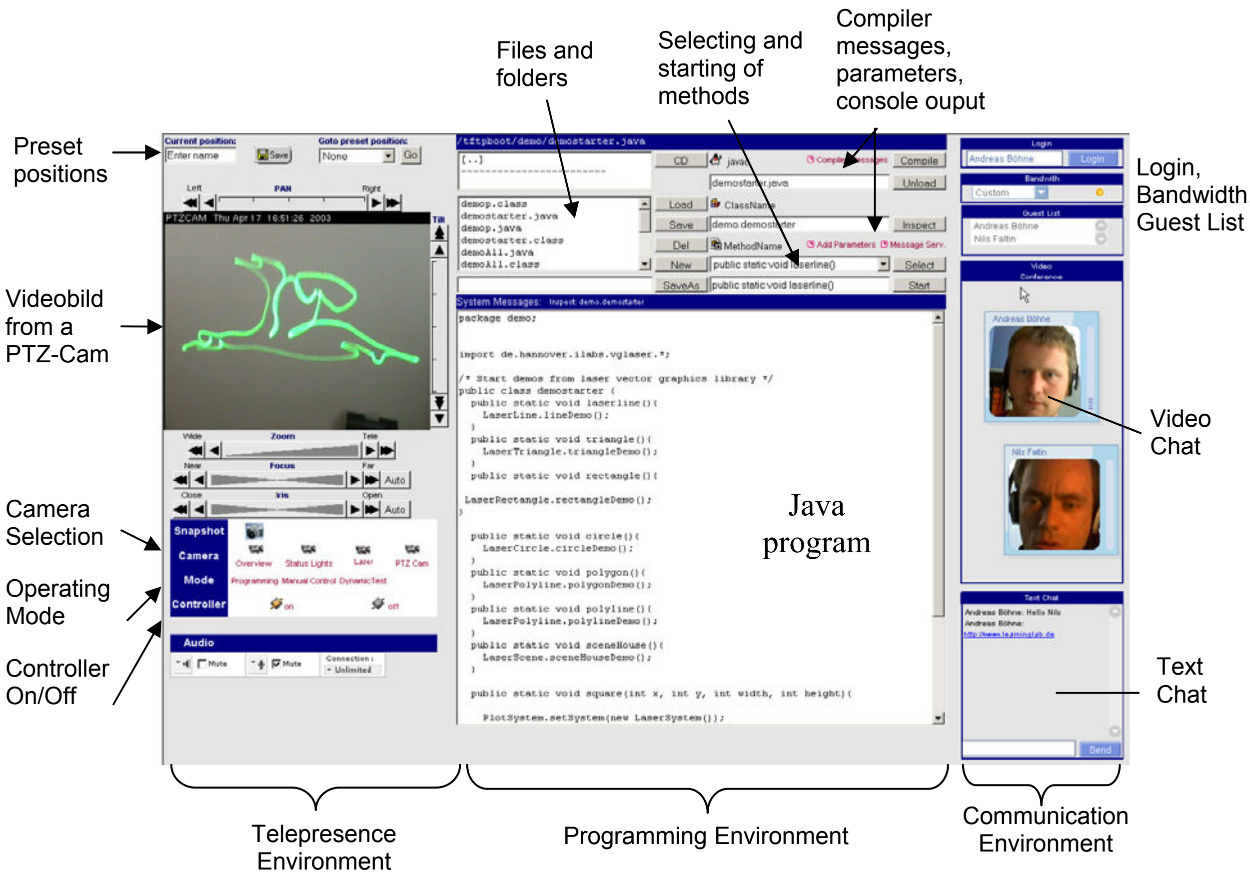

Figure 3: Web Based Lab Environment

We have developed a software library for vector based picture and animation generation in Java. The library eases the development of laser pictures and animations. It supports geometric transformations like translating, scaling and rotating. The library contains classes to create basic shapes like point, line, triangle, rectangle, circle, polyline and polygon. Animations consisting of different frames of laser pictures can be designed. Moreover, animations can be generated with real time properties.

The Remote Experiment in the Laboratory for Process Control

The remote experiment "Picture generation by laser deflection" is one of eight experiments in the laboratory for process control at the University of Hanover and is the only one where students are assisted by a remote tutor. Students learn and apply basics of process control: industrial automation systems, bus systems for process automation, programming of industrial automation systems, hardware-oriented design and remote maintenance. In the summer term 2003, nineteen students of electrical engineering and computer science in the third year of their study took part in this laboratory. Two or three students assigned themselves to a group. Each of the eight groups performed one of the eight experiments per week. The laboratory for process control is not compulsory for the students. In their curriculum they have the choice between different laboratories. Although all students had to take part in a Java programming course in their basic study, we had the experience that only a few students were fluent writing Java programs. In the laser experiment most students got to know real time programming for the first time. Students were used to work with computers and had no problems interacting with the lab environment.

The laser experiment was organized in two phases: preparation for the experiment and practical performing of the experiment. During the preparation of the lab, students familiarized themselves with the documentation of the hard- and software by reading the web based documentation of the laser experiment at home. They completed parts of a Java program for the embedded system. We performed an educational evaluation, so we wanted to provide students equal working conditions. That is why the student groups came to the University, where they had four hours time to perform the lab.

Evaluation Approach

One goal of the field study described below was to show that synchronous remote support by a human tutor is a solution for instructional support in remote labs that has the potential to assist students in an effective way. An obvious way for doing that would be an evaluation study, which compares the learning process and learning results of four different settings: a remote lab with no human tutor, a remote lab with asynchronous support, a remote lab with synchronous support by a human tutor and a remote lab with support by a local human tutor. But because we had a limited number of users and also a research interest regarding self-directed vs. teacher-directed learning, we decided to assist all learners in our study by a synchronous remote tutor, while they worked with the laser experiment (constants of the experimental design, see figure 4). We varied the degree of self-directed learning. According to the evaluation methodology of Borz/ Döring[3], the degree of self-directedness is the independent variable of our experimental design.

Regarding the degree of self-directed learning we implemented two different educational settings. In the **teacher directed setting**, students completed parts of a Java program for the embedded system during the lab preparation. The students needed this program for practically carrying out the laboratory. While working with the experiment they had to deal with four tasks: First they got to know the hard- and software by starting different Java methods that already existed und that generated pictures. In the second task, they measured the dynamic characteristic of the laser system. The results from this task were helpful for the solution of the next task: The students developed a real time Java program for finding the X- and Y-positions of the photosensor. The problem solving process for this task was described in detail and the tutor gave the students subject oriented hints. In the final task the students created a laser picture by using the laser graphic library. In this setting, the tutor acted as e-instructor and explained, for example, the theory of real time programming. Students had to contact the tutor after finishing certain parts of the tasks. The **self-directed setting** gave the students the choice to set their own learning goals. They had the choice between a focus on real time programming (finding the coordinates of the photosensor) or a focus on object oriented programming in Java (generating laser pictures by using the laser graphic library). The lab documents were not specific, but described the tasks only broadly, so students were able to put the tasks in concrete terms. The tutor acted as e-moderator, he supported the students in learning to learn. For example, when the students had questions, the tutor gave them hints, where they were able to find an appropriate answer to their questions in the documentation.

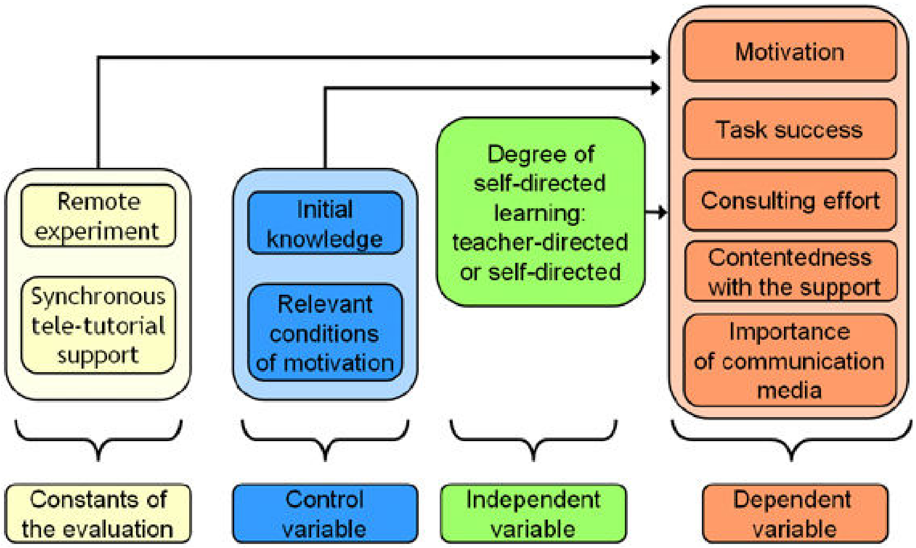

Figure 4: Variables of the experimental design

We defined and measured the dependent and control variables in the following way: In a pretest we asked for the **initial knowledge** relating to the soft- and hardware of the laser experiment and the programming experience in Java. The initial knowledge was measured because we think that it is an important factor in a self-directed learning setting. For example, students, who only have little knowledge of Java programming, will have problems with self-directed learning and need special support from the tutor. Students with experience in programming will be able to work mostly independently. The **consulting effort** is the time effort of the tutor for the support of the students. During the lab session the tutor took notes about the consulting effort and how often a communication media was used. We analyzed the **importance of the different communication media** by taking notes which media was really used by the students during the experiment and by a questionnaire after the lab. In the questionnaire, students rated the importance of desktop sharing, video picture of the tutor, audio chat and text chat for the communication with the tutor (e.g.: "In the remote experiment, the text chat was important", scale: 0=strongly disagree, 5= strongly agree). Our definition of **contentedness with tele-tutorial support** comprises different aspects of the instructional quality: availability of the tutor (one item), clearness and comprehensibility of tutor's explanations (one item), request to contact a local tutor (two items). The **task success** was evaluated by the tutor. He qualitatively assessed the results (e.g.: laser picture, Java program) of a group by comparing the results with other groups and with the pre-determined goals. We distinguished six different **types of motivation**: amotivated, extrinsic, introjected, identified, intrinsic and interested motivation. The **relevant conditions of motivation**, which we measured, are perceived support for content relevance, social relatedness, support for competence and support for autonomy. As described above, this classification of learning motivation types and relevant conditions of motivation is based on the Self Determination Theory (SDT) from Deci, Ryan[4] and the motivation theory from Prenzel et al.[8]. For the measurement of the different types of motivation and the relevant conditions of the learning motivation types we used a validated questionnaire developed by Prenzel.

Results

The execution of the laser experiment took on average M=229min (95% confidence interval=+-13.09, n=8) time. The consulting effort of the tutor was M=86min (±ci=24.72, n=8). So, the tutor and the students communicated on average 38% of the whole lab time with each other. The consulting effort in the teacher-directed setting was higher than in the self-directed setting (self-d.: M=67min, ±ci=47.02, teacher-d.: M=104min, ±ci=25.96, n=4). Because of the large confidence intervals, this difference is not statistically significant. The initial knowledge of the students measured by the pretest was in both settings nearly the same (self-d.: 57.0%, ±ci=14.3, teacher-d.: 64.4%, ±ci=13.4, n=4).

An analysis of tutor's notes show that the video chat was used most (see table 1): On average there were 10.63 contacts between a student group and the tutor during a whole lab session. In each contact the video chat was used. Nearly in each contact tutor and student groups used the desktop sharing tool. The text chat was not so important. It was only used in the beginning of the lab session to find the right audio setting or when there were problems with the video chat. Corresponding to the use of the communication media the importance of the different communication media was rated by the student after the lab (see table 2). They rated the audio channel of the video chat and the desktop sharing as most important. The video picture of the tutor and the text chat was not so important for them. Tutor's ratings were a little bit different from students' ratings. He rated the video picture of the students as useful to gain information about students' working state.

Most students were content with the remote tele-tutorial support (see table 3): The students found it very easy to contact the tutor. Tutor's explanations were rated from most students as clear and comprehensible. Most students did not miss a local tutor resp. they did not wish to contact the tutor face to face.

Number of contacts	**M**	**±ci**
… altogether	10.63	2.09
… with video chat	10.63	2.09
… with desk. sharing	8.25	1.83
… with text chat	0.63	0.89

Table 1: Use of communication media (n=8, 95% confidence interval)

	M	**±ci**
Audio	4.68	0.51
Desktop sharing	4.11	0.46
Video	1.58	0.78
Text chat	1.16	0.59

Table 2: Students' ratings: importance of communication media (scale: 0=strongly disagree, 5= strongly agree, n=19, 95% confidence interval)

Question: In the remote experiment …	M	±ci
… was it easy to contact the tutor.	4.78	0.28
… Tutor's explanations were clear and comprehensible.	3.74	0.27
… I missed direct contact to the tutor.	1.42	0.54
… I wished to contact the tutor face to face.	2.00	0.72

Table 3: Contentedness with tele-tutorial support (scale: 0=strongly disagree, 5=strongly agree, n=19, 95% confidence interval)

Relating the type of motivation, the results contradict our hypothesis, that students will have a more self-determined type of motivation in the self-directed setting than in the teacher directed setting. The characteristics of motivation types in the self-directed and teacher-directed setting were nearly the same (see table 4). In table 5 and 6 one can find a possible explanation that is concurring with the Self-Determination Theory from Deci, Ryan: The students perceived in both settings nearly the same support for competence, autonomy and social relatedness. A correlation analysis between types of motivation and motivation relevant conditions confirms the postulations of self-determination theory: the motivation relevant conditions correlates negatively with amotivation and an extrinsic type of motivation. Perceived support for competence, autonomy and social relatedness correlate positively with an intrinsic or interested type of motivation.

The task success of the student groups were analyzed qualitatively. A quantitative assessment of the task successes was difficult, because groups in the self-directed setting could choose between different tasks. All groups achieved the minimum acting goals of the laser experiment. There was no obvious difference between the task successes of students groups, who learned in the self-directed setting and in the teacher-directed setting. But the solutions and problem solving process of the student groups in the self-directed setting were assessed as more creative by the tutor.

	Self-directed		Teacher-directed	
	M	±ci	M	±ci
amotivated	0.74	0.44	0.85	0.67
extrinsic	0.67	0.51	0.67	0.61
introjected	3.41	0.68	3.63	0.62
identified	2.67	0.44	2.78	0.85
intrinsic	2.59	0.69	2.56	0.82
interested	2.67	0.59	2.48	0.55

Table 4: Characteristics of motivation types (scale: 0=never, 5=frequent, n=9, 95% confidence interval)

Perceived support for …	Self-directed		Teacher-directed	
	M	±ci	M	±ci
Competence	2.48 n=7	0.84	3,09 n=9	0.71
Autonomy	3.45 n=7	0.53	3.41 n=9	0.56
Social relat.	4.00 n=8	0.54	3.96 n=9	0.43

Table 5: Characteristics of motivation relevant conditions (scale: 0=never, 5=frequent, 95% confidence interval)

	amotivated	extrinisic	introjected	identified	intrinsic	interested
Competence (n=16)	-0.23	-0.39	0.22	0.37	0.145	0.42
Autonomy (n=16)	-0.61*	-0.67*	0.27	0.46*	0.63*	0.66*
Social relatedness (n=17)	-0.66*	-0.53*	0.56*	0.27*	0.63*	0.57*

Table 6: Correlations between types of motivation and motivation relevant conditions (*p<0.05)

Discussion

The results of the study confirm our hypothesis that synchronous tele-tutorial support has the potential to assist students in an effective way during the performing of a remote laboratory. Although we did not compare the task success, motivation and contentedness of groups assisted by a local and a remote tutor, the results indicate that a remote support with desktop sharing and video chat can be as effective as a support from a local tutor. Particularly with regard to the fact, that one can assume, that the students compare the quality of the tele-tutorial support in the laser experiment with the support by a local tutor in the other seven experiments of the laboratory of process control. Against this background, for example, the students' rating of tutor's availability must be evaluated: It was easy for them to contact the remote tutor in the laser experiment, because they had not to phone a local tutor to come to the laboratory room from his office as in the other experiments with local support. The relative high consulting effort (86min of 229min) was not caused by the fact that the students were assisted from a remote and not a local tutor. The intensive instructional support by the remote human tutor was necessary, because many students had little experience in Java and real time programming. This interpretation is supported by the short interviews we performed after the lab with the students. Some students said that without instructional support by a human tutor they would not have been able to solve some of the tasks. The request of some students to contact a local tutor show, that a local tutor is the better solution for instructional support, when there is no need from the students and the tutor to choose a flexible learning place. But that most students did not miss the local tutor indicates that synchronous tele-tutorial support provides a good instructional quality, while students can learn in a remote laboratory independent from their learning place. Additional in a remote lab social cues are often not so important. The learning process and subject in a remote lab for engineering education typically does not require a high social relatedness between tutor and students. Students and tutor only have to work for some hours together. Our observation is that most students work task-oriented and time-efficient in a laboratory of engineering education. Tele-tutorial support in a remote lab with video chat and desktop sharing serves the purpose to assist students effectively in this kind of learning process. The hypothesis seems to be plausible, that the absence of social cues is less relevant in a remote lab with tele-tutorial support than in an internet course for acquiring soft skills.

Another goal of this study was to evaluate the importance of different communication media for synchronous instructional support in a remote laboratory. The importance of the audio chat for synchronous tele-tutorial support in students and tutor's point of view meets our expectations. But the results and our observation show also, that only an audio chat is not sufficient for high quality and efficiency of instructional support. The combination of video chat *and* desktop sharing was most important and mostly used. It enabled a smooth communication, collaboration and coordination between the tutor and the students. On the other hand, the combination of video chat and desktop sharing caused problems in our study: The quality of audio transmission decreased on students' side, when the video chat was used together with desktop sharing. This was not caused by a limited bandwidth. The reason was that students' computer had a high CPU load, when the tutor was connected to the computer via VNC and one of the video pictures in the telepresence environment was in the foreground window. An application sharing tool, which optionally allows sharing only specific browser windows, would avoid such a problem. To share only those parts of a web based lab environment which are important for collaboration is not an optimal solution for a smooth collaboration: In our laser experiment, students and the tutor not only shared the programming environment, but also the web based documentation of the programming library. Therefore, our conclusions from the results and from our practical knowledge are: the combination of video chat and desktop sharing makes a communication and collaboration framework available that provides a high quality of instructional support in a remote laboratory with tele-tutorial assistance. An additional text chat should also be provided to solve technical problems with the video chat. When there are bandwidth or CPU load restrictions, an application sharing tool (not a desktop sharing tool like VNC) is recommendable.

Our hypothesis that a self-directed learning setting in a remote laboratory will lead to a more self-determined type of motivation was not confirmed by the results of our study, because the students in both settings perceived the same support for autonomy. We think that the students compared their self-determination in the laser experiment with the self-determination in lectures or other more teacher-directed settings, when they filled out the motivation questionnaire. In relation to a lecture, both settings provided more support of autonomy, so that we were not able to find a significance difference between the settings relating the type of learning motivation. To find an answer to the question, whether the degree of self-directedness influences the motivation and learning results of students in a remote laboratory with tele-tutorial assistance, further research must be done with a greater number of evaluation participants. Our results and observations induce that initial knowledge and quality of instructional support are more important predictors for the motivation and task success of students in a remote lab than gradual differences in the instructional method.

Future Work

With a synchronous communication environment a remote lab becomes an interesting CSCL environment. Several students from different locations can work together on the tasks of a remote laboratory. In the winter term 2003/04 we tested such a scenario with 15 groups of two students. Half of the groups worked as distributed teams with our laser experiment. All groups were assisted by a remote tutor. A first analysis of the data confirms the results of the study described above. Data on differences between collocated and distributed student groups still has to be analyzed.

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Biography

DIPL.-BERUFSPÄD. ANDREAS BÖHNE received his diploma degree in technical education in 2001.He currently pursues his PHD study at the Learning Lab Lower Saxony (L3S), where he works as a team member of the I-Labs ("Internet Assisted Laboratories") project. The project develops didactic concepts for online laboratory usage and reusable software and hardware components.

PROF. DR. PHIL. KLAUS RÜTTERS is managing director of the Institute for Technical Education and Vocational Training at the University of Hanover. He is an associated member of the Learning Lab Lower Saxony (L3S). His research work includes the international comparison of TEVT systems and technical didactics (web based teaching and learning). Furthermore, he worked as a Senior Expert in TEVT system development in several countries (e.g. Korea, China, Gulf States and Thailand).

PROF. DR.-ING. BERNARDO WAGNER has been full professor at the University of Hanover since March 1997. He leads the Real Time Systems Group of the Institute for Systems Engineering. Furthermore, he is member of the directorate of the Learning Lab Lower Saxony (L3S), where he deals with didactic concepts for multimedia and net-based learning environments, especially online laboratories and robotics.