Evaluation of Reduced Perception and Tele-tutorial Support in Remote Automation Technology Laboratories

Nils FALTIN; Andreas BÖHNE; Bernardo WAGNER

Learning Lab Lower Saxony, Expo Plaza 1, 30539 Hannover, Germany,
  {Faltin,Boehne,Wagner}@learninglab.de, www.learninglab.de

KEYWORDS: *remotely controlled laboratories, evaluation, flexible learning*

ABSTRACT: *We develop remotely controlled laboratories for engineering education and technical education in automation technology. With them remote maintenance and remote programming of technical devices are learned. Devices are operated and programmed from a remote location through a web browser and watched through several video cameras. In an automatic control lab valves, pumps, motors and sensors are controlled to move and mix liquids. In a second lab pictures and animations are drawn with a laser beam.*

In one study we evaluated the influence of reduced optical perception of a remotely located device on learning. We compared students working in the same room as the automatic control plant with others seeing it through a pan-tilt-zoom webcam. In a comparative evaluation with 44 technical education students the influence of this reduced visual impression on student motivation, task solving time and knowledge gain was determined. The overall result is that students learned as well in the remote as in the local lab setting as there were no statistically significant differences in student knowledge gain or motivation. There is one exception: time needed to perform tasks did differ significantly in one task where students debugged a malfunctioning control program and located a valve that let liquid pass through. Students needed about 70 % more time when they had to use a video camera.

In a second study we evaluated tele-tutorial support in remote labs. The viability of remote assistance by a tutor and the impact of different kinds of tutor support (degree of student self-directedness) have been evaluated in a laboratory course using the laser display. A remotely located tutor communicated with university engineering students by video conferencing, text chat and desktop sharing. We measured use of communication media, student satisfaction, tutor support time and task success. Remote assistance proved to work very well, with desktop sharing and audio transmission being the most important communication media. The tutor support style did not have a statistically significant influence on learning.

1 INTRODUCTION

In contrast to local laboratories, remotely controlled laboratories allow students to learn independent from time and place. This flexibility can aid students in better fitting laboratory work in their individual study schedule. It is especially important for part time and off-campus students that have long distances to travel to come to a local laboratory on campus.

But replacing the direct contact to the experiment devices and to other persons by a computer mediated interaction and communication does limit the information transferred. It is no longer possible to touch, smell and see in full detail the experiment devices. In human communication many non verbal signals (like facial expressions, gestures and pointing to an object) get lost. It is our ambition to evaluate whether this has a negative impact on learning when performing an engineering education laboratory. In a first study we compared a local with a remote laboratory by evaluating the impact of reduced visual impression of a technical plant on learning. In the second study we assessed the feasibility of remote tutorial support and the impact of different tutor support styles.

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],[6],[11]]. Therefore, in typical laboratories, students can get assistance from a tutor. Often small student groups of two or three students work jointly on a laboratory experiment. This allows them to complement each other in knowledge, creativity and control of procedures and thus reduces the amount of tutorial support needed per student. Also students in general value this social setting of tutor and fellow students for the support and motivation it yields.

2   THE IMPACT OF REDUCED VISUAL PERCEPTION IN A REMOTE LAB

A remotely controlled laboratory for process control was built that is modelled after industrial technical plants. The experiment (Fig. 1) consists of a Programmable Logic Controller (PLC), two tanks that serve as liquid reservoirs and a central reactor tank for mixing and heating the liquids. Each tank is equipped with liquid level sensors and an outlet valve. In a real technical plant the mixed liquid would be dispersed from the machine. In the model, the mixed liquid is fed into a storage tank and is pumped back to the two reservoirs.
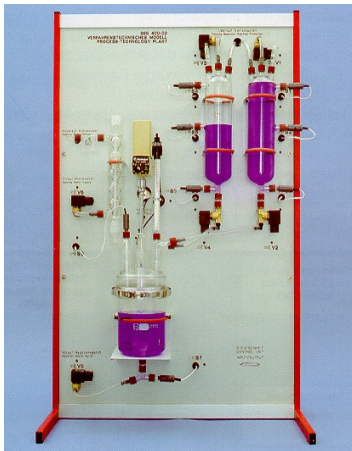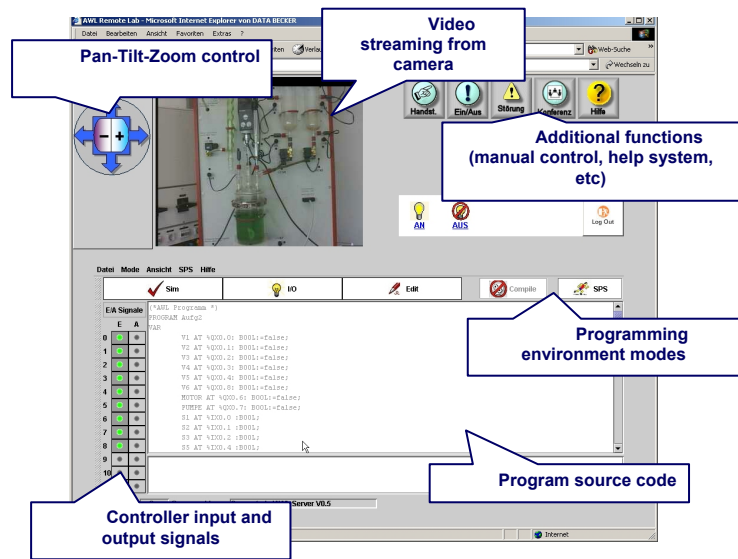

Figure 1 – Process control plant   Figure 2 – Web based laboratory environment

The experiment is controlled through a web based laboratory environment (Fig. 2). Users can watch the experiment through two pan-tilt-zoom cameras. They can directly operate the experiment through a manual control interface, watching sensor status and controlling output ports to actuators like pumps and valves. But the preferred operating mode is to write a control program in the Instruction List language and execute it on the PLC. Program development consists of editing, storing, compiling and uploading a control program and is also done in the web based lab environment.

In the evaluation this laboratory was used with mechatronics students from German technical schools. During their three year mechatronics education students are employed at a company where they are integrated into the normal work process or learn in specialized workshops. One or two days a week they attend the technical school. Some companies were asked to send the students to the evaluation during their regular work hours. Most companies were willing to do so and 48 participants could be recruited. Of these, 44 showed up in the required teams of two.

Students worked in groups of two with the laboratory in a room at the University of Hannover and had four hours time for the tasks. Information on the experiment, the programming language and the tasks was available in hypermedia documents. Student tasks were:

1. to empty the reservoirs and the reactor into the storage tank.
2. to identify the cause that the machine behaviour was not consistent with the specification of the process when executing a given PLC program and to correct the corresponding control program.
3. to extend the program to support On and Off switches.
4. to extend the program to stop when the pump ran without water.

Student groups were randomly assigned to a local or remote condition. In the local condition students worked in the same room as the experiment and had thus direct eye contact to the experiment. In the remote condition students worked in a different room and could only observe the machine through the user-controlled video cameras. Software and hardware for interacting with the experiment were identical in both conditions. Before they worked on the tasks students filled out online questionnaires to determine their computer literacy and performed an online test to assess their declarative knowledge in the programming language.. Dependent variables measured were 1) motivation and acceptance, 2) quality of problem solving strategy, and 3) increase in declarative knowledge. Motivation was determined through questionnaires after the laboratory session based on the Self Determination Theory of Deci/Ryan [9] and the Interest theory of Prenzel [8]. Quality of problem solving process was determined through observing the time students needed to solve each task and logging the number of compiler and program test runs. Declarative knowledge was measured after the experiment similar to the pre test, although with slightly different questions.

A summary of the evaluation results can be found in [[13]] and will be published in detail in a doctoral thesis. There was no statistically significant difference in motivation/acceptance and increase in declarative knowledge between conditions. Time needed by students for the tasks is detailed in table 1. The mean time needed for task 1 (empty tanks) and task 3 (correction of program) are very similar and not of statistically significant difference. Task 2 (identify wrong behavior) shows a large difference in time needed, with the remote groups needing about 70 % more time to complete the task. This difference is statistically significant. Only 5 of the 11 remote and 6 of the 11 local groups managed to complete task 4 (extend program) within the total time of 4 hours for the session. Thus the difference in mean time needed by these groups are not statistically significant, although large in absolute terms.

Task	Remote condition			Local condition		
	Mean	Min	Max	**Mean**	Min	Max
1) empty tanks	**22,2**	7	51	**21,8**	7	40
2) identify wrong behavior and correct program	**52,8**	31	105	**31,3**	16	51
3) On and Off switches	**117,5**	45	193	**119,7**	61	207
4) Stop when pumping without water	**67,3**	45	91	**92,1**	66	140

Table 1: Student time on Task [minutes]

In the case of control and programming of a machine, results indicate that working remotely instead of locally with an experiment does not significantly impede learning. When the task involves scanning the machine visually for abnormal behaviour and focussing on suspicious details, time needed for the task does increase largely. But this does not have a negative influence on motivation/acceptance and knowledge increase.

3   EVALUATION OF TELE-TUTORIAL SUPPORT

Research Questions

CSCW research has already analyzed 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 [[7]] emphasized the absence of social cues in text-based communication. Mark et al. [[8]] reported the benefits from desktop sharing for distributed working groups. Sonnenwald [[12]] 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 [[14]]:

- 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 post processing 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 [[8]].

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]]. We only give a short overview of the tutor-support style part of the evaluation here, a more detailed presentation can be found in [[3]].

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 3). 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.
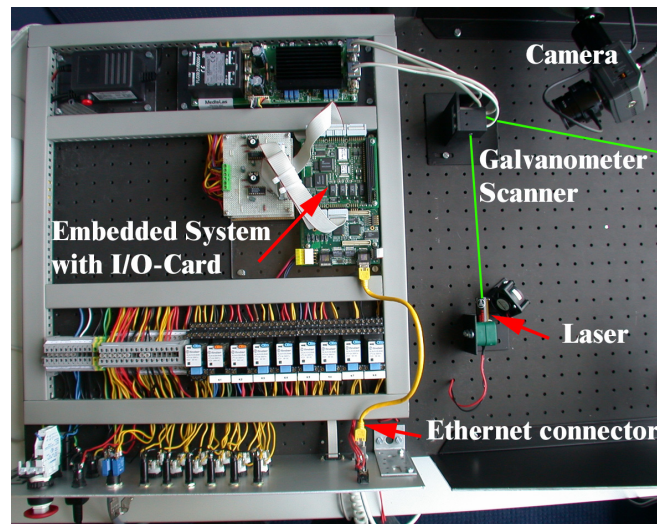
Figure 3: Laser experiment components

Students generate pictures by developing embedded Java programs in a web based programming environment (figure 4, 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 4 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 4 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 4, 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.
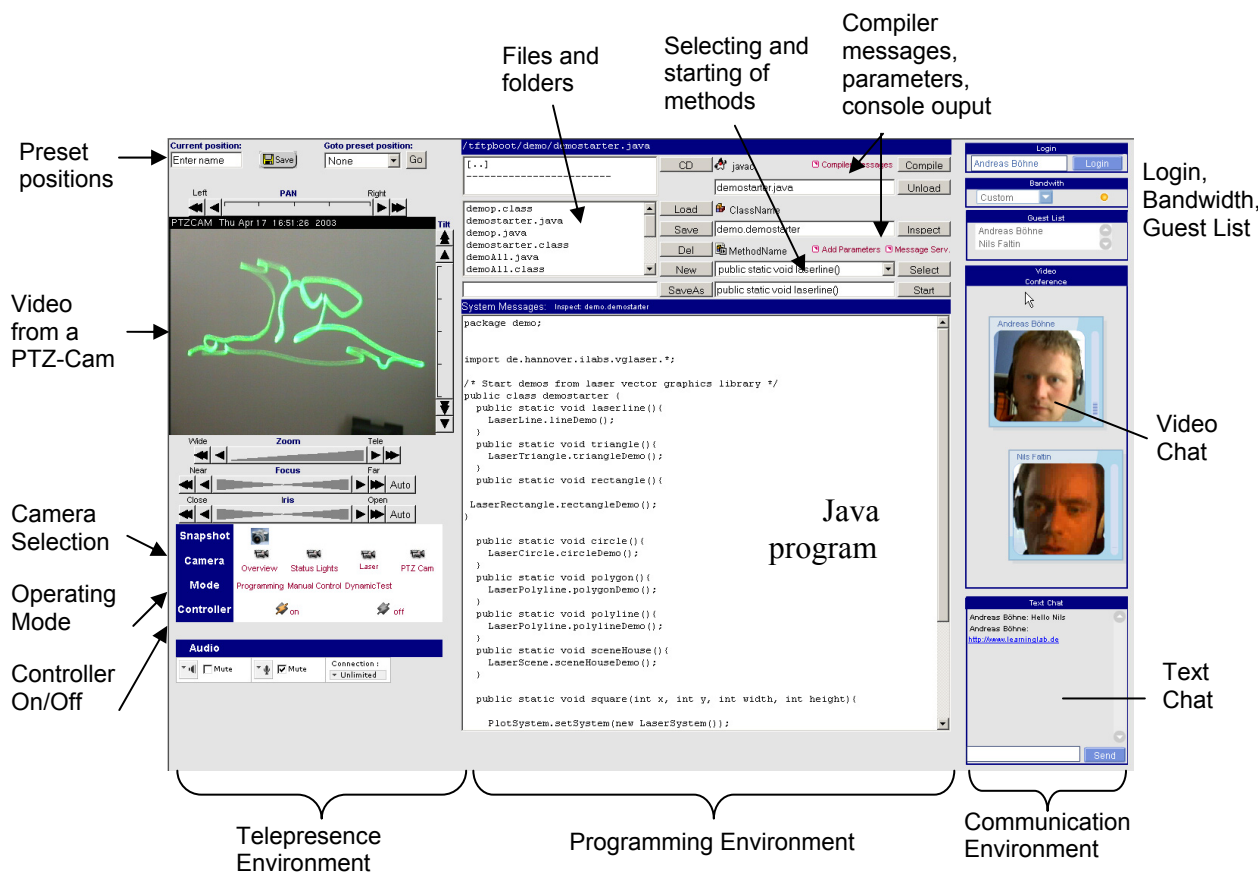
Figure 4: Web Based Lab Environment

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 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 tutor, a remote lab with asynchronous support, a remote lab with synchronous support by a tutor and a remote lab with support by a local 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). We varied the degree of self-directed learning. According to the evaluation methodology of Borz/ Döring [[4]], the degree of self-directedness is the independent variable of our experimental design.

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. In the final task the students created a laser picture by using the laser graphic library.

We defined and measured the dependent and control variables in the following way: In a pretest we determined the **initial knowledge** relating to the soft- and hardware of the laser experiment and the programming experience in Java. 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.

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 2): 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 3). 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 4): 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 2: 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 3: 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 4: Contentedness with tele-tutorial support (scale: 0=strongly disagree, 5=strongly agree, n=19, 95% confidence interval)

Regarding 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. Also, 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.

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 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 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.

The kind of tutorial support, whether it was teacher-directed or self-directed, did not have a statistically significant influence on learning. A possible explanation is that working in a programming laboratory already is an inherently self-directed task, so that the psychological need for autonomy is already fulfilled to a large extent. This way further raising autonomy does not raise motivation or task success.

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.

ACKNOWLEDGEMENTS

REFERENCES

[1] Böhne, A., Faltin, N., Wagner, B., "Synchronous Tele-tutorial Support in a Remote Laboratory for Process Control", International Conference on Engineering Education, July 21-25, 2003, Valencia, Spain

[2] Böhne, A., Faltin, N., Wagner, B., "Self-directed Learning and Tutorial Assistance in a Remote Laboratory", Interactive Computer Aided Learning Conference (ICL), September 25-27, 2002, Villach, Austria

[3] Böhne, A., Rütters, K., Wagner, B., "Evaluation of Tele-tutorial Support in a Remote Programming Laboratory", American Society for Engineering Education Annual Conference 2004, June 20-23, 2004, Salt Lake City, Utah, USA.

[4] Bortz, J., Döring, N., "Forschungsmethoden und Evaluation für Human und Sozialwissenschaftler", Springer, 2002

[5] Deci, E., L., Ryan, R., M., "Overview of Self-Determination Theory: An Organismic Dialectical Theory", In: Deci, E., L., Ryan, R., M. (ed.), Handbook of Self-Determination Research, University of Rochester Press, 2002, pp. 3-33

[6] Geyken, A., Mandl, H., Reiter, W., "Selbstgesteuertes Lernen mit Tele-Tutoring", In: R. Schwarzer (ed.), MultiMedia und TeleLearning. Lernen im Cyberspace, Frankfurt, 1998, pp. 182-196

[7] Kiesler, S., Siegel, J., McGuire, T., W., "Social Psychological Aspects of Computer-Mediated Communication", In: American Psychologist, Vol. 39, No. 10, October 1984, pp. 1123-1134

[8] Mark, G., Grudin, J., Poltrock, S., E., "An Empirical Study of Virtually Collocated Teams", In: Proceedings of ESCW`99, The 6th European Conference on Computer Supported Cooperative Work, September 12-16, 1999, Copenhagen, Denmark, pp. 159-178

[9] Prenzel, M., Kristen, A., Dengler, P., Ettle, R., Beer, T., "Selbstbestimmt motiviertes und interessiertes Lernen in der kaufmännischen Erstausbildung", Zeitschrift für Berufs- und Wirtschaftspädagogik (ZBW), 1996, 13, pp. 108-127

[10] Reeve, J., „ Self-Determination Theory applied to Educational Settings", In: Deci, E., L., Ryan, R., M. (ed.), Handbook of Self-Determination Research, University of Rochester Press, 2002, pp. 183-203

[11] Reinmann-Rothmeier,G., Mandl, H., "Unterrichten und Lernumgebungen gestalten", In: Krapp, Weidemann (ed.): Pädagogische Psychologie, Beltz, 2001, pp. 601-646

[12] Sonnenwald, D., H., Whitton, M., C., Maglaughin, K., L., "Evaluating a Scientific Collaboratory: Results of a Controlled Experiment", In: ACM Transactions on Computer-Human Interaction, Vol. 10, No. 2, June 2003, pp. 150–176

[13] Tuttas, J., Wagner, B., "Telepresent vs. Traditional Learning Environments – A Field Study", International Conference on Engineering Education, July 21-25, 2003, Valencia, Spain

[14] Wessner, M., Pfister, H.-R., „Kooperatives Lehren und Lernen", In: Schwabe, G., Streitz, N., Unland, R., CSCW-Kompendium, Springer, 2001, pp. 251-263