Distributed Team Learning in an Internet-Assisted Laboratory

Nils Faltin[1], Andreas Böhne, Jörg Tuttas and Bernardo Wagner

Abstract *¾ While many simulations have been developed, only few projects provide access to real experiments through the Internet. A shortcoming of most remote laboratories is that they do not support distributed team learning with tutorial assistance. We describe the technical and educational concept of distributed internet assisted laboratory experiments (I-Labs). We present the I-Labs project, its goals and research questions. Currently we work on a remote experiment where students develop an embedded controller program which serves the deflection unit of a laser system. Our educational concept is based on self-directed and collaborative learning with tutorial assistance. Learning strategies and outcomes will be evaluated comparing self-directed and teacher-directed learning in co-located and distributed settings. The results shall help future developers of remote labs to choose an appropriate educational setting.*

Index Terms ¾ collaborative learning, remote laboratory, self-directed learning, tutorial assistance.

REMOTE LABS VERSUS LOCAL LABS

Laboratories are important elements in technical education. They allow applying and testing theoretical knowledge in practical learning situations. Students working in a local lab can directly see, hear, touch and smell the laboratory devices. This full impression of being in the lab cannot be provided by remote labs where students interact with remote devices through a computer user interface. That is why remote labs are called by Aktan the "Second Best to Being There" [1]. So students should have the opportunity to work with local labs to get a direct "hands on" experience.

But there are good reasons to provide students with remote labs too. Remote labs can be shared by many institutions and students worldwide. Given a constant amount of money, students can have the opportunity of access to many more remote labs than local labs. As an example, in the German LearnNet network each of the seven universities provides a remote lab to all members [7]. Distance education and learning-on-the-job students benefit even more from remote labs, as the cost and time needed for traveling to a local lab would often prevent them from using such labs. Working with remote experiments will develop engineering skills like remote maintenance of devices. When students work in distributed teams they also learn how to act in remote collaboration. Some experiments in areas like nano physics [6] can not be accessed by human hands and eyes anyway, so students do not loose anything by working remotely.

REMOTE LABS VERSUS SIMULATIONS

Instead of building a remote lab one can in many cases develop a software based simulation of the experiment. While the cost of developing a veridical simulation can be high, once developed it can be copied and distributed at low cost, so cost does not limit the number of simulation users. While a remote lab can be shared by many students working at different times, only one student at a time can use a lab device. To provide access for several parallel users to one experiment type, one has to build and maintain several instances of the experiment devices, which may result in a substantial cost per student.

But remote labs do have some advantages over simulations which stem from the point that remote labs include reality into the experiment: (1) A goal of engineering education is to prepare students to cope with problems of real devices and systems. While simulations tend to be too simplistic, remote experiments naturally demonstrate problems of measurement tolerance, device failure and difficulties to return to a start state. (2) Remote labs allow the verification of scientific theories. In the Scientific Method, theory has to be evaluated by testing hypothesis in real experiments. (3) As an evaluation of a remote lab showed, students like to perceive and influence reality [10].

THE I-LABS PROJECT AND ITS REMOTE EXPERIMENTS

Our project "Internet assisted Laboratories (I-Labs)" is a cooperation of the Stanford Center for Innovations in Learning (http://scil.stanford.edu), California, and the Learning Lab Lower Saxony (http://www.learninglab.de), Germany, within the Wallenberg Global Learning Network. In Stanford optical experiments for physics education and in Hanover mechatronic devices for engineering education are developed. By working with a remote lab students shall learn to program, maintain and supervise remote devices. The I-Labs project will develop didactic concepts for online laboratory usage and reusable software and hardware components. Together with newly gained design knowledge it will make it easier to develop new online labs.

In one of our experiments, students program an industrial controller (PLC) for a process engineering plant. In this process, a fluid can be moved between several tanks

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and mixed and heated in a reactor. The experiment has been evaluated with university students of electrical engineering [10]. It has subsequently been adapted for use in technical schools. We will measure students' knowledge gain, problem solving strategies and motivation comparing a local and a remote learning setting. In the local setting students and the experiment are in one room. In the remote setting, students and the experiment are in separate locations [11].

We are currently developing an experiment for picture generation by laser deflection. Students will write embedded Java programs to generate pictures. The new remote lab reuses several components of the previous experiment for handling fluids. Both labs are used in a problem based learning setting.

We decided to develop the picture generation experiment because of the following criteria:

- The learning subject fits into the course on industrial process control for engineering education.
- It is maintenance free, so it can be provided for long term use.
- It gives users a visible result and provides high feedback, which we expect to lead to high student motivation.
- It can be displayed and run in a public place.

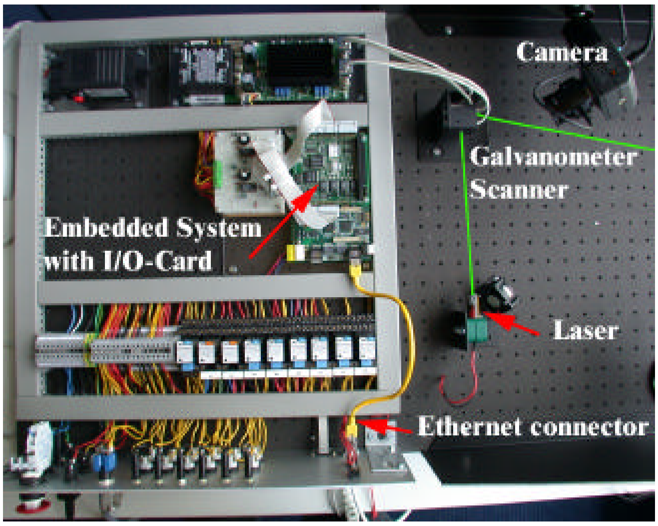

FIGURE 1
LASER EXPERIMENT COMPONENTS

The experiment system consists of a green 3mW laser beam which is deflected by two mirrors of a galvanometer scanner in X- and Y-direction (fig. 1 and 2). The scanner can move the beam to 30,000 positions per second. The deflection is controlled by two analogue inputs to the scanner. They are driven by DA-converters controlled by an I/O-Card in an embedded system. A web server is running on the embedded system. It allows users to control the I/O signals through a web browser. Students generate pictures by developing embedded Java programs in a web based programming environment. It allows editing, storing, compiling, uploading and running of programs. Video cameras allow remote users to see the experiment desk and the generated picture. The picture can be projected onto a room wall or a canvas. A microphone will transmit the sound of the operating scanner via an audio server. A lab scheduling component allows administrators and users to reserve time for using the lab. The program development environment and the scheduling component are implemented with Java Server Pages (JSP) and a MySQL database.

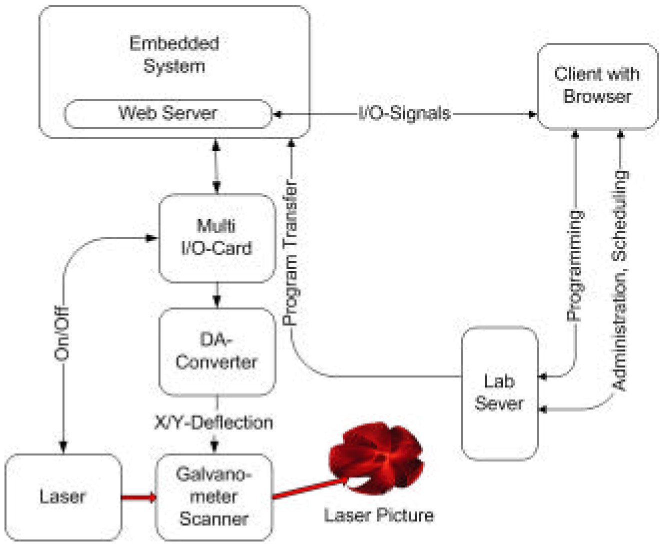

FIGURE 2
BLOCK DIAGRAM LASER EXPERIMENT

EDUCATIONAL CONCEPT AND RESEARCH QUESTIONS

The educational concept for our new laser experiment lab combines self-directed and collaborative learning with tutorial assistance. In line with the constructivist paradigm, students deal with the teaching and learning environment in groups and in a situated context. The context is situated because programming an embedded system is a relevant task in engineering practice. A strong emphasis of our concept is put on self-directed learning.

Self-directed Learning

Self-directed learning seeks to put the learner as much as possible in control of the learning process. It is the learner rather than an institution, a teacher or a learning program who chooses the educational objectives, emphases and learning strategies. Learners set their own goals, analyze a given problem, observe the learning progress and assess the learning results. However, it is not practical to demand completely autonomous learning. For example even when a web based course gives the learner a maximum of autonomy the contents and structures are typically fixed and thus limit self-directed learning. Self-directed learning seeks to maximize the learners' freedom of choice in the following dimensions [8]:

- learning goals (relating to the subject or the aspiration level)
- media and resources
- learning place
- learning time, speed and duration
- social setting (e.g.: group learning or learning alone)
- learning strategy (e.g. depth and sequence of processing subject elements).

Our remote labs are web based. Concerning the dimensions above, web based learning has a high potential to support self-directed learning in the following aspects [4][3]:

- Learning is independent of time and place.
- The hypermedia structure supports the exploration of the learning content.
- Learners need feedback to sustain motivation. When no teacher is available, interactive elements can provide some feedback.
- The learning environment can adapt the learning materials to the needs of the learner.

Learners in continuing education have a special need for flexible, self-directed learning. They need to choose the learning content according to their actual needs. It is not practical to demand that they work through a large predefined curriculum. As they have a fixed work schedule they need to choose the learning time and place. Web based learning will save travel time and cost.

Self-directed learning poses high demands on the personality of the learners because of their responsibility for the learning process. That is why the demands of the learning environment should be in balance with the competences of the learners for self-directed learning:

> "Consequently, self-direction in learning is a term recognizing both external factors that facilitate a learner taking primary responsibility, and internal factors that predispose an adult accepting responsibility for learning-related thoughts and actions. At the same time there is a strong connection between self-directed learning and learner self-direction. Both internal and external aspects of self-direction can be viewed on a continuum and optimal learning conditions exist when a learner's level of self-direction is balanced with the extent to which self-directed learning opportunities are possible." [5].

For self-directed learning, a learner should have the following competences [8][9]:

- self-observation, self-reflection, self-judgment
- development of own objectives
- reactivation of initial knowledge
- autonomous organization of learning (e.g.: time management)
- autonomous development of learning motivation and concentration
- development of learning and problem solving strategies
- knowing when to seek the assistance of other learners or the tutor

Often students are only used to learn in a teacher-directed setting, so that a long term goal should be to develop these competences for self-directed learning. Many students abort their learning when they get stuck in a web based learning environment and can not get help. To allow typical learners to perform well in a self-directed setting, they need support by a tutor. A tutor can help with organizing the learning process, solve technical problems and answer questions regarding the content. We think that a human tutor is needed as it is not possible to prepare every thinkable learning task and support information in advance.

The general question in designing environments for self-directed learning is which degree of self-directed learning is suitable for which goals and which students under which conditions. The evaluation of our remote laboratory described below will contribute to answering this question by comparing the effectiveness of two learning settings with a varying degree of self-directedness.

Tutorial Assistance

In our educational concept a tutor assists the learners in their self-directed learning. The tutor resides at a remote location and communicates through synchronous media. He can support the learners in several ways:

- He can give information and assistance in questions concerning the content or referring to technical problems.
- He can stimulate the meta-cognition of the learners.
- He can advise on the choice of the learning goals and acting goals.
- He can give feedback to motivate the students.
- He can organize the learning process and set time limits.

Another task of a tutor in a remote lab can be the design, realization and administration of the learning environment. Moreover he can form groups, moderate group discussions and coordinate the interaction within the group.

In our laser experiment the students will act in distributed teams and communicate with each other and a tutor by synchronous tools like videoconference, chat and application sharing.

In our evaluation we will compare two settings with different tutor roles:

- In the self-directed setting 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.
- In the teacher-directed setting 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.

We also want to investigate which technical tools for communication and collaboration are suitable for a remote lab with a remote tutor.

Collaborative Learning

In our remote labs, groups of students work with an experiment. We decided to implement a collaborative approach because of the following reasons:

- The social relatedness promotes the motivation of the students.
- Students can help each other.
- Students acquire social competence in team work. When students are located at different places they also acquire skills in remote collaboration.
- The consulting effort per student decreases. Given a constant amount of tutor time, the possible number of participants, who can use the experiment, rises.

Working in a group limits the freedom and self-directedness of a single student. The student must coordinate the preparation and implementation of the lab with the other students in his group. But the character of self-directed learning is not lost in a collaborative setting. Self-directed learning should not be confused with absolute autonomy.

In our evaluation we will compare a setting where students are co-located with a setting where they are distributed over several locations. This will give us evidence whether student collaboration works sufficiently well in a distributed setting.

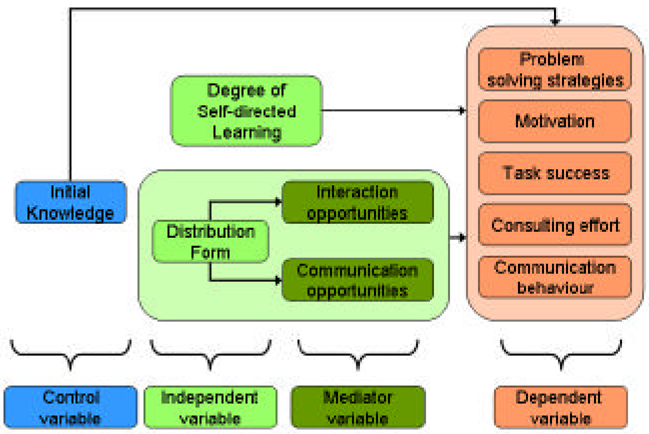

FIGURE 3
VARIABLES OF THE RESEARCH QUESTION

EVALUATION APPROACH

We will perform a comparative evaluation study. We are following the evaluation methodology of Borz/ Döring and distinguish independent, dependent, mediator and control variables [2]. Our main research question is: How does the distribution form and the degree of self control considering initial knowledge influence problem solving strategy, motivation, task success, consulting effort and communication behaviour? To this end, we will vary the independent variables distribution form and degree of self-directed learning (see figure 3).

We will distinguish two different **distribution forms**: In the first setting all students are in one location, the experiment and the tutor are at remote locations. In the second distribution form each learner, tutor and the experiment are at separate locations (see figure 4).

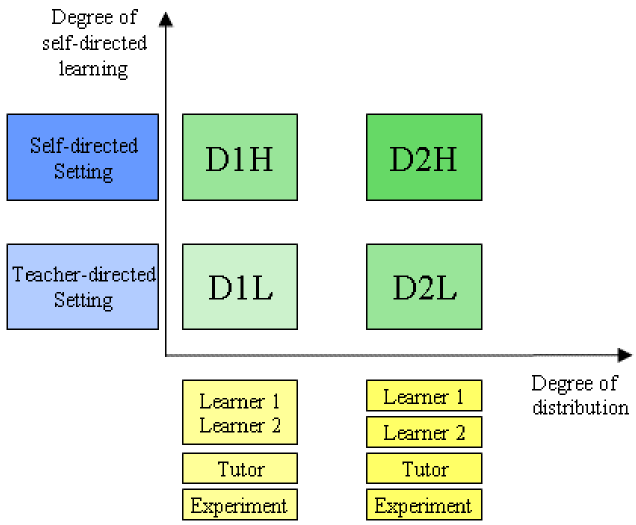

FIGURE 4
2X2 DESIGN OF INDEPENDENT VARIABLES

Regarding the **degree of self-directed learning** we will implement two different educational settings (see table I):

1. *Self-directed.* High degree of self-direction of the students in the dimensions learning goals, tasks and tutor role.
2. *Teacher-directed.* Low degree of self-direction in these dimensions.

TABLE I
DEGREES OF SELF-DIRECTED LEARNING

Dimensions of self-directed learning	Self-directed setting	Teacher-directed setting
Learning goals and tasks	After some pre-determined tasks, the group develops the learning goals and tasks. The tutor approves goals and tasks.	Predetermined tasks with increasing difficulty.
Role of the tutor	e-coach, e-moderator	e-instructor

An important point in self-directed web based learning environments is the students' ability to freely choose learning time and place. Unfortunately it is very difficult to perform a comparative study with such a setting. Several variables like work environment, work time and available support materials would be very different from student group to student group and hard to measure. The variability of these variables would endanger the reliability of our study. We plan to perform a qualitative study in the future, where students are free to choose learning time and place.

We have defined the dependent, control and mediator variables in the following way: When students are distributed they have to communicate over synchronous communication media like video, audio, whiteboard, chat and application sharing. When students are co-located they can communicate directly. The **communication opportunities** are the media, which are available for the students for communication among the students and for communication with the tutor. The media used for the interaction student-experiment (e.g.: video, audio, programming environment) are the **interaction opportunities**. With **communication behavior** we describe the media, which are really used by the students during the experiment. The content of the communication will be logged and summarized qualitatively. The **consulting effort** is the time effort of the tutor for the support of the students. We will differentiate between the support for technical questions, questions concerning the content, learning process and moderation of the collaborative work. The **task success** is evaluated by the tutor. He assesses the results (e.g.: laser picture, Java program) of the group by comparing the results with other groups and with the pre-determined goals. The **motivation** is distinguished in types of extrinsic and intrinsic motivation. **Problem solving strategies** are mental represented schemes to find operations for solving concrete problems. The **initial knowledge** is measured with a questionnaire before the experiment, 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 of the tutor. Students with experience in programming will be able to work mostly independently.

We will use qualitative and quantitative methods for the acquisition of the necessary data. To measure the dependent and control variables we will design questionnaires and pre tests. We will observe the learners' activities during the experiment by logging all communication and interaction.

We will evaluate our laser experiment in the winter term for the first time. Then students of electrical engineering take part in the laboratory for industrial control. In this first evaluation we will vary the degree of self-directed learning with co-located students (settings D1H and D1L in figure 4). The complete evaluation will be performed in the following summer term.

CONCLUSION

In the I-Labs project, we develop an educational concept for collaborative, self-directed learning with tutorial assistance in online laboratories. Also, reusable software and hardware components for remote laboratories will be delivered. We are currently building a new experiment for picture generation by laser deflection.

Up to date only a small number of remote labs have been built in research projects. The future will show which organizational model will succeed in providing a large pool of remote labs for continuing use. Remote labs can be shared by a network of educational institutions where each institution provides labs for the participating partners. Another model for the provision of remote labs is that commercial providers maintain the labs and lease lab time to educational institutions. In any case remote labs will be used by institutions with different curricula and student background. This calls for a flexible educational setting like the one described above based on self-directed learning and tutorial assistance.

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