VIRTUAL AND REMOTE LABS IN PHYSICS EDUCATION

(Extended abstract)

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Introduction, Virtual and Remote Labs, Demonstration of Examples

A computer simulation which enables essential functions of laboratory experiments to be carried out on a computer is called a virtual laboratory (VL). Two major conceptions of this idea can be differentiated:

a) In the first constellation an experiment is replaced by a computer model. The experiment therefore takes place in the form of a simulation. Recently, virtual laboratories have emerged above all on the Internet (World Wide Web). However, these experimental virtual laboratories in JAVA format (and also those in VRML- and Shock-wave-Format) mainly represent classic simulations, which are not intended to represent laboratory experiments in a realistic fashion. Simulations which attempt to represent the real laboratory experiments as closely as possible we call virtual labs.

b) On the other hand, laboratory experiments can be described as virtual when the experiments are controlled not by direct manipulation of laboratory equipment, but by means of a computer, which is linked up to the actual laboratory equipment via a network (for instance, via the WWW). This type of virtual laboratory is called remote lab.

Generally speaking, virtual laboratories, like simulations, are intended to transfer conceptual and procedural knowledge. Since this knowledge refers to the preparation, the performance and the evaluation of laboratory experiments, it is necessary to impart both background knowledge and also knowledge referring to actually carrying out the experiment.

As with simulations in general, virtual labs can also facilitate a range of different learning processes: solution of (complex) problems; discovery of new content and new assessment of already known information by means of discovery learning; construction of general principles from experimental work and comparison of individual phenomena (inductive learning). In all these cases the alternation between generating hypotheses and testing hypotheses is of particular importance.

Especially in the context of virtual labs another aspect plays an important role: due to their realistic representation they provide opportunities for situative learning environments.

A good *starting point* is calling back to mind the traditionals goals of the introductory physics laboratory. The AAPT summarized them as follows:

I. The Art of Experimentation;
II. Experimental and Analytical Skills;
III. Conceptual Learning;
IV. Understanding the Basis of Knowledge in Physics;
V. Developing Collaborative Learning Skills.

In the context of our paper the following statement is central: *„The digital computer is an important tool of inquiry in scientific research. However, computer simulations should not be used as substitutes for direct experience with physics apparatus. All laboratory students should have an opportunity to gain confidence in their ability to ‚troubleshoot' and tinker with mechanical, thermal, optical and electrical systems"*.

We agree in principle with this statement. Especially VL should be used for the preparation of the real labs (*pre-lab function*) and only for the partial substitution of practical laboratory sessions (*lab function*).

Walkington et. al. (1994) have listed four groups of aims for practical work in engineering which are mostly in agreement with the AAPT:

1. *To support the learning of theory*
   - *by illustrating/demonstrating phenomena*
   - *by applying theory to real situations*
   - *by demonstrating the limitations of theory*
   - *by interacting with phenomena in authentic situations*
2. *To develop a body of knowledge*
   - *about materials, devices and techniques*
   - *about safety codes and practices*
   - *about specific equipment and techniques*
3. *To develop a body of skills involving*
   - *manual skills*
   - *critical observation, interpretation and assessment*
   - *diagnostic skills*
   - *planning and organization*
   - *practical problem solving*
4. *To develop attitudes which*
   - *stimulate an interest for engineering*
   - *highlight 'getting the job done'*
   - *generate self confidence in all areas*

And the authors have additionally linked these aims to off-campus strategies. As a result of their analysis one can conclude that videos and CAL can improve the situation. Particularly manual skills, planning and organization have to be learned in a real context. We assume that VL could help to develop these skills because the realistic representation of the lab situation provides opportunities for situative learning.

We defined VL as a computer simulation which enables essential functions of laboratory experiments to be carried out on a computer.

Cramer et. al. (1997) gave a different definition: *„We define a ‚virtual laboratory' as a software simulation of an experiment whose output data is indistinguishable from data from a ‚real' physics experiment."*
They added a vision about the network-based virtual laboratory of the future and introduced the terms ‚theory-based virtual laboratory', ‚experimentally-based virtual laboratory' and ‚hybrid virtual laboratory':
„If a theory exists for the phenomenon in question, one can create a theory-based virtual laboratory. These have the advantage of allowing the user complete freedom in exploring parameter space. They are superb tools for investigating the consequences, often unforseen, of our equations. One can also construct an experimentally-based virtual laboratory. In this case, one stores experimental measurements in digital form and combines it with a user interface. Ideally, one wishes to create both of these, resulting in a hybrid virtual laboratory. The hybrid type provides a singularly effective means of comparing theory and experiment. With such a lab, students can apply the scientific method with complete rigor to every phenomenon they encounter."

However, currently the term virtual laboratory is used for very different sorts of simulations. We tried to classify the existing state-of-the-art virtual labs according to 5 categories:

1. Classical simulations which contain certain elements of laboratory experiments and are available locally (*Simulations*).
2. Classical simulations which contain certain elements of laboratory experiments, are accessible on the Web (on-line) and are available as JAVA-Applets (or accessible with plug-ins) (*Cyber Labs*).
3. Simulations which attempt to represent laboratory experiments as closely as possible (*Virtual Labs*).
4. Simulations of lab experiments using virtual reality techniques (*VR Labs*).
5. Real experiments which are controlled via network / Internet (*Remote Labs*).

In the first part of the workshop we want to demonstrate examples of the five categories.

Real experiments which are controlled via network / Internet are called remote labs. Till today remote labs are designed and used mainly for control engineering laboratories and especially in the field of robotics. The first realization was the project "Second Best to Being There (SBBT)" which started in 1994 at the Oregon State University. The goal was to provide remote students with complete access to the undergraduate control engineering laboratory.

Another initiative is the remote lab of the Carnegie Mellon University. It deals with electronic experiments (and does not use robot arms). A good example comes from Germany. It is called CYBERLAB, developed at the University of Osnabrueck. This is a real remote lab controlled via Internet for analyzing the polarized light emission of scattering events.

The College of Engineering and Computer Science at the University of Tennessee at Chattanooga offers a Resource Center for Engineering Laboratories on the Web. One can use computer-based systems for data acquisition and control that have been installed in an engineering laboratory used to teach classical control techniques. The engineering parameters that are the subjects of the various control stations are speed, pressure, flow, position, liquid level, and temperature. All systems have data acquisition and control programs with an operating interface which simulates a traditional analog process controller. The programs are used by students for parameter identification of the various systems and then used to tune the controller action (proportional and/or integral actions). Results of step response and frequency response experiments are used for system identification and design. A new development is the delivery of control panels to control the remote lab via TCP/IP.

Besides other initiative the Australia’s Telerobot should be mentioned. Developed by the University of Western Australia it can be used to control a robot together with video cameras.

Within the German initiative in the state of Baden-Wuerttemberg called “Virtual University” the Virtual Laboratory Collaboration (VVL) should be mentioned. It is a collaboration of 5 Universities of Applied Sciences and the University of Tuebingen in building and using remote & virtual labs in engineering education. Especially they are studying Virtual and Telematic Robot Laboratory, Automatic Systems, Optic 2D-Measuring, Telematic and Automatic Control, Virtual Pneumatic Training Systems, 3D Pattern Recognition. (http://www.vvl.de)

Second part of the workshop:

Hands-on practicals

With the help of a worksheet the participants have to make their own experiences with some examples of virtual and remote labs. Some examples can be accessed locally, but most of the examples require an internet connection and a Web-browser with appropriate plug-ins.

Third part of the workshop:

Discussion of the role of virtual and remote labs in physics education

If one looks for empirical evidence, evaluation and research results on virtual and remote labs, one has to admit that only very few publications can be found. Mosterman et. al.(1994) and Campbell (1997) reported on their research on the Electronic Laboratory Simulator (ELS): *„Using an Electronic Laboratory Simulator (ELS) we can*

1. *produce performance on both written and lab tests that is equivalent to or better than that of students using physical labs in a beginning circuits course at the undergraduate level*
2. *decrease the need for both equipment and lab space, thus potentially saving money.*
3. *decrease the time in physical labs*

4. *decrease the requirement for teaching assistants in physical labs*
5. *eliminate labs at non-preferred times (e.g. nights and weekends) and provide students the flexibility to take a lab in their dorm or at home at times they choose.*"

In their first evaluation study students were randomly assigned to two groups of 10 students each. One group taking the VL first and the physical lab next; the other group taking the lab in reverse order. The important comparisons are between the time required, and the number of requests for assistance when students took the VL before the physical lab. Students taking the physical lab first required 73% longer meantime. The mean value of the number of questions asked of the teaching assistants was 157% higher.

Edward (1997) stressed the importance of realism in the screen presentation of an engine. The one is schematically the other faithful (realistic). The first is easier to use, but the second gained considerably more practical appreciation. He concluded that simulations are less effective than the actual lab but that realism minimises the disadvantages.

Finally we want to summarise and discuss the role of virtual and remote labs in physics education, e.g. coming back to our starting point about the goals of the introductory physics lab: to what extent could virtual and remote labs provide the five goals, what are the current and principle restrictions and how could we imagine future developments of virtual and remote labs.

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