# A New Virtual and Remote Experimental Environment for Teaching and Learning Science

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**Abstract.** This paper describes how a scientifically exact and problem-solving-oriented remote and virtual science experimental environment might help to build a new strategy for science education. The main features are: the remote observations and control of real world phenomena, their processing and evaluation, verification of hypotheses combined with the development of critical thinking, supported by sophisticated relevant information search, classification and storing tools and collaborative environment, supporting argumentative writing and teamwork, public presentations and defense of achieved results, all either in real presence, in telepresence or in combination of both. Only then real understanding of generalized science laws and their consequences can be developed. This science learning and teaching environment (called ROL - Remote and Open Laboratory), has been developed and used by Charles University in Prague since 1996, offered to science students in both formal and informal learning, and also to science teachers within their professional development studies, since 2003.

**Keywords:** remote laboratory, blended learning, science education

## 1. Introduction

### 1.1 Contemporary problems in Science Education – the needs

Contemporary problems in science education are closely connected to a general teaching and learning paradigm shift, as a result of the reality of the globalized world together with the information revolution and ongoing knowledge society needs.

According to Derrick [3], some general features can be recognized in this movement, and all of them should be reflected in teaching and learning science.

- A focus on uncertain (not exactly defined) situations

Much of the academic environment today, presents students with ready-made problems, but the reality is rarely that clearly defined. Today's learners and teachers have to be more familiar and comfortable with uncertain situations.

- A focus on conceptual understanding

Conceptual understanding is the ability to apply knowledge across a variety of instances or circumstances. Several strategies can be used to teach and assess concepts, e.g., inquiry, exposition, analogies, mnemonics, imagery, concept maps, and concept questions.

- Uses a holistic, as opposed to discrete, approach

Much of the education and learning environment today is still divided into rigid academic disciplines, focused on discrete units of research. However, the holistic understanding of systems thinking and inter-disciplinary research approaches are seen as critical to achieving a more comprehensive understanding of the complex reality currently facing the world system.

- Team work and virtual teams around the world

There are many arguments that collaborative learning (also computer-supported or mediated) enhances team performance through tools for communicating each person's ideas, structuring group dialogue and decision making, recording the rationales for choices, and facilitating collective activities. Closely related to this point is the need for enhanced virtual and networked activity.

- Blur the difference between mental and physical labour

The global system of production and distribution is based upon the blurring of the distinctions between mental and physical labour and the increase in the application of knowledge to the production process itself [3]. This change is so significant that it represents a fundamental shift for much of the world, and it is necessary to respect it in underlying teaching and learning strategies.

### 1.2 Contemporary problems in science teaching – the reality

The general teaching and learning paradigm shift mentioned above is not yet reflected in contemporary teaching methods at many traditional teaching and learning environments.

Over the past couple of decades, science education researchers have studied the effectiveness of existing teaching and learning practices: conceptual understanding, transfer of information and ideas, beliefs about science and problem solving in science. The definitive conclusion is that no matter what the quality of the teacher, typical students in a traditionally taught course are learning mechanically, memorizing facts and recipes for problem solving, but not gaining a true understanding. In spite of the best efforts of teachers, students often consider science boring and irrelevant to the world around them.

### 1.3 The role of cognition of real world phenomena in science

There is no doubt that lab-based courses, in particular, play an important role in scientific education and mainly in the cognition of the real world.

Clough [2] goes so far as to claim that "hands-on experience is at the heart of science learning" and declares that laboratory experiences "make science come alive." Lab courses have a strong impact on students' learning outcomes, according to [8]. The role of labs in sciences is well described in the very instructive and still valid document of the American Association of Physics Teachers [1], formulating five goals that the physics laboratory should achieve.

## 2. E-labs – General Issues

At the present time, information and communication technologies have invaded science education in all directions. They have undoubtedly changed the laboratory "landscape".

The nature and practices of laboratories have been changed dramatically by the new technology-intensive automations:

- simulated labs (also called virtual labs),
- remote labs, and
- computer mediated hands-on labs as an alternative for conventional hands-on labs.

The present state of art is characterized as reaching the level of the quantitative increase of parameters that can bring about very deep qualitative changes. In the very recent issue of European Journal of Physics, devoted to Student undergraduate laboratory and project work, Schumacher [13] brings the examples of the invasion of computers in contemporary laboratory work reaching from project labs, modeling tools, interactive screen experiments, remotely controlled labs, etc. It is plausible to adopt the statement that these kinds of e-labs will be the typical learning environment for physics students in the future.

### 2.1 Educational issues of e-labs

Although the researchers still discuss each type of e-lab from different perspectives, the relative effectiveness of the new laboratories compared to traditional hands-on ("recipe based") labs seems to be undoubted. The following aspects are often discussed:

- Design skills
- Conceptual understanding
- Social skills (including team work and networking)
- Professional skills

Although there is a lack of criteria for judging and the evaluation of the effectiveness of the three new types of labs: computer mediated hands-on, virtual and remote labs, the results of the comparative literature study [7], including more then 60 research studies, are very instructive.

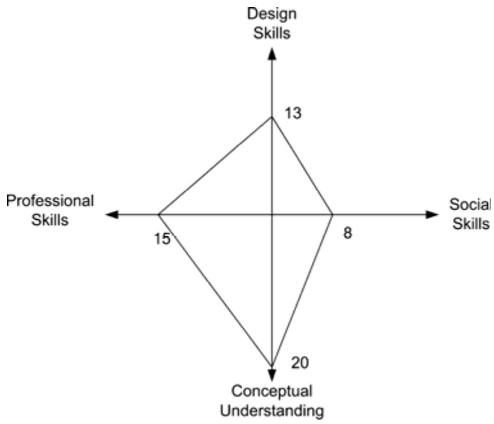


**Fig. 1** Educational goals of hands-on labs [7]

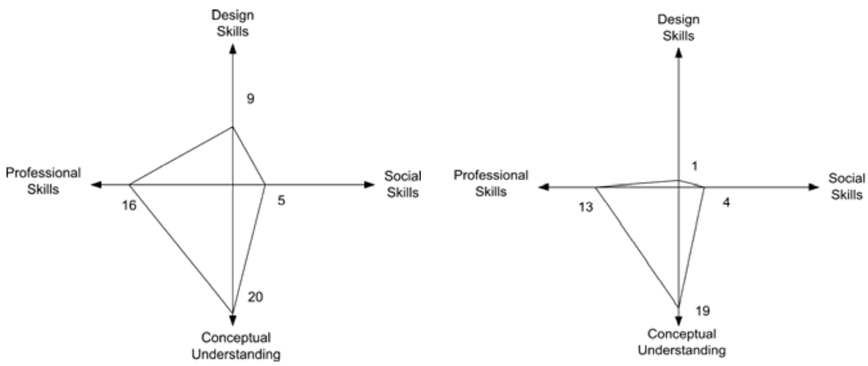


**Fig. 2** Educational goals of e-labs – a)virtual labs (left), b) remote labs (right) [7]

### 2.2 Economic issues

As a backdrop for these phenomenological issues (more details in [7]), there is a set of economic issues.

Traditional hands-on labs put a high demand on space, instructor time, expensive apparatus and experimental infrastructure, often in a number of identical lab stations, which can be little used for other purposes. All of these aspects are subject to rising costs. Remote and virtual laboratories may provide a way to share specialized skills and resources (also with research institutions) and thus to reduce overall costs and enrich the learning experience.

### 2.3 Psychological issues and the problem of "presence"

Sheridan [9] identified three types of presence: physical presence, telepresence, and virtual presence. Physical presence is associated with real labs and understood as "physically being there."

Telepresence is "feeling like you are actually there at the remote site of operation," and virtual presence is "feeling like you are present in the environment generated by the computer". The author argued that by suspending disbelief, we can experience presence in a virtual environment. Others claimed that the critical issue in designing virtual environments is to create a psychologically real setting rather than to recreate the entire physical reality. In our strategy we offer students the combination of all three kinds of presence identified by Sheridan.

### 2.4 New e-learning strategy in science education

The motivation and inspiration for this new e-learning strategy in science education came from our own research work on remote and open laboratories (ROL project) [4],[5], introducing the very early stage of virtual presence through a remote labs potential for blended learning in Science, then from the recent paper of Wieman [15] and Wieman, Perkins [16], supporting and calling for the change in the educational technology, seeing the remedy at hand in the existence of simulations, and also from Thomsen and his co-workers [14], who present the new approach called e-LTR (eLearning, eTeaching, eResearch ) using the remote experiments (RLC). They also introduce eResearch, based on the existing e-laboratories, composed of the remote internet-mediated experiments, enabled to fill link (missing till recently) to e-Learning.

This new e-learning strategy in science education is actually copied from the method that sciences use in their cognitive work. It is based on the observations of phenomena in the real world, together with the processing and interpretation of ensuing data and their presentation, and the effective search for relevant information and effective ways of classification and storing. Teachers are not bound by strict rules of the teaching unit; some unveiled problems are proposed to students for their own independent and project work.

The learning process itself is based on the active participation of students, whose involvement is strengthened by dynamical simulations of the real phenomena, co-operative teamwork (both real and virtual), public presentations and the defence of achieved results, all either in real presence or in telepresence.

## 3. ROL components and first experience

### 3.1 Remote observation and data collection

This set of modules teaches basic concepts in remote sensing. Learners are shown how characteristics of the system and sensors are used, and how they affect the amount and quality of data collected. A sampling of ways to use the data for activities such as weather forecasting and scientific research are demonstrated. At the completion of each module, learners are given opportunities to apply what they have learned to actual data collected by MFF researchers.

Learners are starting from the simplest observations (weather observations - temperature, air pressure, wind speed and direction, sunshine, etc.,) and continue to more and more sophisticated data acquisition and research design.

### 3.2 Hands-on remote labs and process control

The oldest, most popular and the most fun part of this blended learning environment is the "hands on" remote laboratory, which allows learners to operate equipment such as simple robots, mechatronic systems, programmable logic controllers and wet process control systems over the Internet. It includes detailed expert instruction, video and audio feedback and evaluation. Each component takes students through a complete, progressive learning system that first teaches through simulation, and then allows interaction through real-time remote lab operation.


**Fig. 3** Remote process controlling – Charles University in Prague

### 3.3 E-simulations (virtual labs)

Virtual lab tools offer a large variety of e-simulations and models, including Java applets, Flash visualization and/or different kinds of computer mediated mathematical models. Applets were primarily developed to visualize the phenomena and help to understanding in a graphic way. They are not primarily focused on data providing, although some of the applet creators enable the drawing out of the full data set. That is why the vast majority of virtual laboratories, spread all over the “web world”, do not provide the data output or input we need in science for the comparison of real experiments and models. The new and the most far-sighted branch of applets or models, offered by the Remote and Open Lab, is connected to the real experimental setup (even physically) and thus enables the import of real measured data as well as their simulation.

### 3.4 E-simulation in connection to real data acquisition and process controlling

This sophisticated and complex approach enables students to observe specific and rare phenomena (earthquakes for example) without losing the sense of being in a place, to manipulate remotely dangerous objects and chemicals in a very safe way, and to accomplish complicated measurement and data acquisition on a high level without being lost in technical problems and setups; and thus to focus on conceptual understanding through different methodological approaches (e.g., social constructivism - virtual team discussion and co-operation tools, consultancy services, or individual inquiry– e.g. real data and mathematical simulation results comparison).

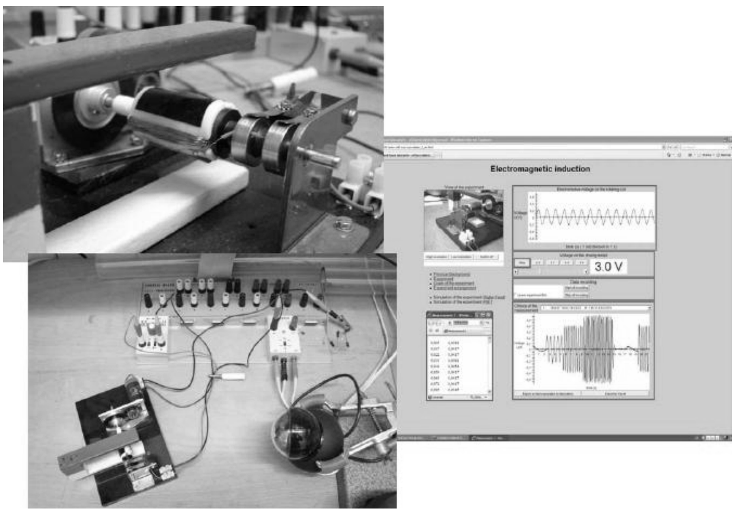


**Fig.4** Real remote data collection and process controlling in connection with e-simulation and modelling – Charles University in Prague

As an example of what is mentioned above, we propose the Heisenberg uncertainty principle experiment, which experimental setup enables telepresence through computer mediated mechanical manipulation with real objects (e.g. laser, aperture), computer-mediated set up of the experiment (frequency of the light, parameters of the aperture ) and through visual observation of the observed phenomena (web camera). It also enables computer aided data acquisition (pure data and visualized data – graph), together with the possibility for immediate comparison of the real data and simulated results.

### 3.5 E-worksheets for the teamwork

The new e-learning strategy is part of interactive teaching and learning, based on the observation of the real world phenomena by the real E-experiment and E-simulations, and includes also e-teaching and learning tools and interactive E-worksheets for team work, and E-manuals and instructions providing information and theoretical background for the understanding and quantification of observed phenomena.

The E-worksheets present the theory, offering exercises and pre-solved problems, glossaries for quick orientation in the theory covered, and multiple-choice tests with immediate evaluation of the acquired knowledge, etc.

## 4. Conclusions

Although the whole problem of the cognition of the real world via remote tools has many philosophical and methodological aspects, and the effective use of blended learning environments based on it definitely needs further research, in the following we would like to publish selected conclusions, based on a comparative literature review (11 papers, results obtained from different schools of physics and faculties, preparing physics teachers - e.g. [10], [11]). Most of the reviewed papers' authors adopted e-labs within the two-semester course of an introductory physics laboratory, oriented mainly toward mechanical and thermal properties, electric and non-electric properties, oscillations, waves and optics, and microphysical phenomena. The data collection was computerized, mostly by ISES, some experiments (app. one half) were designed to use different tools and methods of proposed ROL environment, including virtual consultancy services and e-sheets for the virtual team work. The comparative study has not yet been published.

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