Remote and Open Laboratory in Science Education – Technological, Educational and Psychological Issues

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Abstract. This paper will describe 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 of the new strategy are (1) the remote observations and control of real world phenomena, possibly materialized in data, their processing and evaluation, (2) verification of hypotheses combined with the development of critical thinking, supported by (3) sophisticated relevant information search, classification and storing tools and (4) collaborative environment, supporting argumentative writing and teamwork.

Remote and Open Laboratory has been developed and used by Charles University in Prague since 1996, offered to science students and teachers since 2003.

Keywords. Remote laboratories, e-learning, telepresence, science education.

1. Background

1.1. Contemporary problems in science teaching – the reality

Derrick in [2] identified contemporary problems in science education and their close connection 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.

He has identified general features and postulated recommendations:

- Turn the focus from ready made problems and situations to uncertain ones
- Focus to conceptual understanding
- Uses a holistic, as opposed to discrete, approach
- Support team work and virtual teams around the world
- Blur the difference between mental and physical labour

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 (e.g. [11], [12], etc.). The definitive conclusion is that no matter what the quality of the teacher is, 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.

1.2. The role of labs and the cognition of real phenomena in science

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, briefly described as following:
• The Art of Experimentation
• Experimental and Analytical Skills
• Conceptual Learning
• Understanding the Basis of Knowledge in Physics
• Developing Collaborative Learning Skills

2. Contemporary labs: E-labs

2.1. 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:
• Virtual labs (also called simulated labs),
• Remote labs, and
• Computer mediated hands-on labs as an alternative for conventional hands-on labs.

The present state of art is characterised 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 [11] brings the examples of the invasion of computers in contemporary laboratory work reaching from project labs, modelling 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.

2.2. Educational issues of e-labs

Although the researchers still discuss each type of e-labs 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 (Ma, Nickerson, [6]), including more than 60 research studies, are very instructive.
2.3. Economic issues

As a backdrop for these phenomenological issues (more details in Ma, Nickerson, [6]), 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.

2.4. Psychological issues and the problem of “presence”

Sheridan [7] 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. Noel and Hunter [6] 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.

3. 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) (Lustigova, Zelenda, [3], [4], [5]), introducing the very early stage of virtual presence through a remote labs potential for blended learning in Science. Then it came from the recent paper of Wieman [13] and Wieman, Perkins [14], supporting and calling for the change in the educational technology, and also from Thomsen and his co-workers [12], who presented the new approach called e-LTR (eLearning, eTeaching, eResearch) using the remote experiments (RLC). They also introduced 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 defense of achieved results, all either in real presence or in telepresence.

4. ROL components and first experience

4.1. 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., see Fig.3) and continue to more and more sophisticated data acquisition and research design.

4.2. 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.

4.3. 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.

4.4. 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).

As an example of what is mentioned above, we propose the diffraction on microobject experiments (www.ises.info/index.php/en/laboratory/experiment/diffraction-on-microobjects) or Heisenberg uncertainty principle experiment (www.ises.info/index.php/en/laboratory/experiment/heisenberg-uncertainty-principle), which experimental setups enable 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. 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 present some conclusions, based on a comparative literature review (11 papers, results obtained from different schools of physics and faculties, preparing physics teachers - e.g. Schauer, Kuritka, Lustig, [8], Schauer, Lustig, Ozvoldova [9], etc.). Most of the reviewed papers’ authors adopt our lab 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 was not published, yet.

Students:
As part of the development we are constantly evaluating it and are including student feedback into its improvements. We discuss student reactions to this new way of gaining practical experience and understanding. Generally, student responses are positive and are improving over the years as the technology becomes more available and the students get more experienced in using it. Although students are quite often aware of the limitations of the remote and open laboratories they also value their advantages: 1/ at any time from any place, 2/ remote access, 3/ simple and comfortable operating and control (mentioned mainly by girls) and safety. From social and psychological point of view they appreciate mostly virtual consultancy support and the potential for building virtual teams (to lose the feeling of the loneliness in the lab). From an educational point of view it is the immediate comparison of real (measured) and simulated data, which is appreciated the most.

Faculty:
Although remote and open laboratory use is frequently put forward as a new way of working, the management of complexity, uncertainty, and communication in science education and research, and integrating selected parts of ROL - the remote data acquisition, data processing and process control theme across the curriculum- is not a completely seamless process. That is why the Remote and Open laboratory is offered to students in a parallel way to traditional labs. Mostly students with part or full time jobs, distance students, in-service teachers and both faculty members and students involved in professional training and life long learning use these facilities.

6. References


