# Web Based Catalogue of Online Experiments

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***Abstract* — A knowledge base of online experiments was built. It is a kind of catalogue describing online experiments used for educational purposes. Metadata for describing this special kind of learning resources and analysis of experiments available in the catalogue (both virtual and remote) are presented in this paper. Examples of online lab experiments and exercises are developed by different European universities are also described.**

***Index Terms* — metadata, knowledge base catalogue, simulation, virtual and remote experiments.**

## I. Introduction

An engineer not only has to adapt theoretical knowledge to his practical work but actually to control, manage, improve and develop technological processes and aggregates. To teach these skills, practical work and experimentation should play a key role in an engineering curriculum.

Besides real experiments in a local laboratory there are now two types of online experiments and laboratories: virtual and remotely controlled. In a local experiment, students operate real devices and manipulate and measure real objects while being directly co-located with the devices and objects in the same room. Virtual experiments are based on mathematical modelling and simulation [1-5]. They contain software simulations of experiments and pre-recorded measurements, pictures and videos but do not manipulate real objects. They can be realised as local or distributed software applications. Remote experiments do offer remote access to real laboratory equipment, workbenches and experiments via the Internet [6-11].

Remote and virtual experiments offer greater flexibility and provide access for more students within a given time frame and to a large number of experiments & simulations while reducing the total acquisition, operating and maintaining costs. Virtual and remote laboratories can support group work over the Internet and can be shared by students working from multiple distant locations.

Another task of online experiments and labs is virtual replacement of equipment that is not available or cannot be used for educational purposes. It is of particular importance for complex technological processes, aggregates and systems in the chemical, metallurgical, fuel and energy branches which cannot be studied integrally in a local lab due to their enormous complexity. Laboratory equipment and facilities at universities are designed to study only separate phenomena, reactions, phases or zones of such complex technological processes.

Online experiments should be directly linked to other online tools and resources (text and reference books, recorded and/or live lectures, and other interactive and instructive material).

Presently a project “Network of Excellence in Professional Learning (ProLEARN)” funded by the European Union strives to integrate European activities in e-Learning into a powerful and meaningful community in order to establish Europe as a world leader in this field. The mission of a consortium of 19 European universities and research centres as well as more than 100 associated (also non-European) partners is “to bring together the most important research groups in the area of professional learning, as well as other key organisations and industrial participants, thus bridging the currently existing gap between research and education at universities and similar organisations and training and continuous education that is provided for and within companies" [12]. One of the working groups is dealing with online laboratories and namely with integration of European research in this field [13]. Many online experiments, virtual simulations and labs, which are of great importance especially for engineering education, have been developed during the last several years.

A Web based catalogue of online experiments descriptions has been created recently by this group to provide an overview of existing online experiments and laboratories. It is a kind of electronic online repository of experiment descriptions, allowing educators, experiment developers and educational researchers to locate online experiments of interest. They can then contact the experiment owner for further information and negotiate access rights to the experiment, obtain technical information for building their own lab or obtain scientific articles on educational evaluations.

## II. KNOWLEDGE BASE CATALOGUE

A content management system was set up to store the online experiment descriptions according to the metadata schema. It is possible to enter descriptions and search for descriptions over the Internet through a Web-based user interface. Access to store and retrieve descriptions is free of charge.

### *A. The online experiment catalogue platform*

The online experiment catalogue is available at the EducaNext portal which is a global platform for the exchange of educational content and sharing of knowledge. Developed as the result of the European e-Learning project Universal, this platform is in operation since 2003 and allows [14]:

- To participate in Knowledge Communities;
- To communicate with experts in fields of interests;
- To exchange learning resources;
- To work together on the production of educational material: textbooks, lecture notes, case studies, simulations, etc.;
- To deliver distributed educational activities: lectures, courses, workshops, case study discussions, etc.;
- To distribute electronic content under license.

The EducaNext portal is implemented using a distributed multi-lingual, Web-based, learning content management system, called the Universal Brokerage Platform (UBP) [15]. It combines the features of a reference catalogue, allowing users to enter links to their content made available via dispersed delivery systems, with the features of a digital library where users can upload asynchronous learning resources. The core features of the UBP are the support of an exchange process, the integration of heterogeneous delivery systems, and a user-friendly and flexible metadata model.

EducaNext orchestrates a sophisticated exchange process between providers who wish to make their electronic content available to a wide audience. Special features allow EducaNext content providers to customise their offers. They can specify the community to which they wish to make their content available and the type of exchange relationship they wish to establish with consumers. Although any Web browser may freely consult the EducaNext catalogue, users who wish to have access to certain learning resources are required to register themselves with the portal. Thus "consumers" agree to the conditions under which they may reuse a provider's content and EducaNext tracks the entire exchange process between providers and consumers so that providers know who is using their content, in the interest of community building.

The UBP provides access to a wide variety of learning resources made available through a heterogeneous set of delivery systems such as video conferencing applications, learning management systems, streaming media servers and standard Web servers. Tele-tutors and other providers of tele-conferences and remote lectures can announce these academic events via the portal and grant access to video conferencing applications or streaming media servers to selected users. Course administrators at learning management systems can publish a complete course or a small learning object [16]. Content stored at Web servers can be simply referenced via hyperlinks.

*B. Online Experiment Metadata: structure and specific attributes*

The online experiments metadata schema is the format for describing online experiments, much like the schema behind a library catalogue is used to describe the books in a library. According to [17] metadata is cataloguing information about content that facilitates its labelling, indexing, search, storage, retrieval, execution, display, licensing, maintenance, and/or use. It contains attributes describing the learning resource and providing hints on its usage. The UBP is designed in alignment with existing metadata standards.

*As an online experiment is a special kind of learning object, our schema was specified as an extension to an established metadata schema for learning objects. The additional attributes were specified and online experiments were integrated as a new educational material type.*

Extended metadata include beside general, technical and educational metadata information sections also the new section Internet-based online experiment.

The general information section has standard attributes such as title, authors or contributors, language, description, discipline, learning resource category as well as typical learning time.

The Description is an attribute for storing free text descriptions of a learning resource. For an experiment it should cover the following points:

- the experiment setup (components and their role)
- interaction modes and manuals (like manual control or programming)
- documentation on technical and theoretical background
- task descriptions
- experiences of using the experiment in education.

The learning resource category “Experiments” is split into “Experiments (offline)” (downloadable simulations / virtual experiments) and “Experiments (online)” (requiring a permanent Internet connection from the learner to the experiment, as is the case for remote experiments and some high performance and group work based simulations).

The technical information section includes such attributes as format, size and technical requirements.

The educational information section consists of following attributes: educational objectives, method of instruction, location of additional information, curriculum. Additionally, a specific taxonomy of learning resources distinguishing between educational material and educational activities do exist.

Beside these three information sections a new one “Internet-based Online Experiment” was developed and implemented for online experiments. It consists of a number of additional attributes: experiment components, number of setups, supported interaction modes, availability, and reservation.

*An Internet based experiment* is an experiment that requires an Internet connection from the client PC to a server to run the experiment. Purely virtual experiments that can be run without an Internet connection are not “Internet based experiments”. This does not imply that an Internet based experiment is of remote type only. The experiment can be made up of any combination of virtual, remote and local components. But the server needs to be up and running (Availability) and the case when several users try to access an experiment needs to be handled (Reservation). Often guests are allowed to work with an experiment on a restricted basis (Guest access).

Attribute Experiment components: it is quite common to have experiments with combinations of local, remote and virtual components. For example, many remote experiments include a virtual component. This allows students to train with the simulation before using the real experiment. When a real experiment set-up both can be used locally in a laboratory and controlled over a distance, it has both remote and local components [18].

Experiment component types contain:

- virtual experiment component
- remote experiment component
- local experiment component

Attribute group Number of Setups: An experiment may be provided in several set-ups. These set-ups can be used independently and determine the number of simultaneous active users. An active user controls an experiment. Additionally there may be passive users that watch the actions of the active user and the reaction of the experiment.

- number of set-ups
- number of active users per set-up
- number of passive users per set-up
- allocation policy (policy used to assign a set-up to a user. Priority of user classes and contingent of set-ups. Assignment to the previously used set-up, if available.)

Attribute Supported interaction mode: In *synchronous interaction* a user is connected to an experiment for a significant time (at least some minutes). He interacts with the experiment in a series of steps that build upon each other. Each step consists of the user sending a command to the experiment that changes its state and then observing the changed state, typically through live video and signal scopes.

In *asynchronous interaction* there is only one such step. Users prepare a command and send it to the experiment. The command is processed and the result sent back to the user. The experiment then automatically goes back to a predefined start state.

Attribute Availability: The *Availability* indicates at which times the server is up and running so users can connect to the experiment. This may be limited for remote experiments as they often need regular maintenance. Some large and potentially dangerous experiments may even need to be switched on and supervised by a technician. It may also happen that institutions providing online laboratory equipment block time slots for their own students.

Possible values are:

- Continuously (The experiment is available all year during the whole day. It may be down for maintenance for a short time.)
- Planned time interval (The experiment is available during certain pre-planned time spans (e.g. the lecture period) and maybe during certain hours (e.g. business hours, when technicians are at work). The planned time interval is stated in the text field.)
- Upon request (The experiment is not offered as a regular service. But the owner is willing to switch it on upon request. Users should contact the experiment owner to arrange this.)
- Not available (The experiment does not exist anymore or it is not known when it will become available again).

Attribute Reservation: The case when several users try to access a synchronous experiment needs to be treated. The number of simultaneous users will be limited. It can therefore be required to reserve a timeslot to use the experiment. Asynchronous experiments will typically use the “Stand in Queue” reservation strategy.

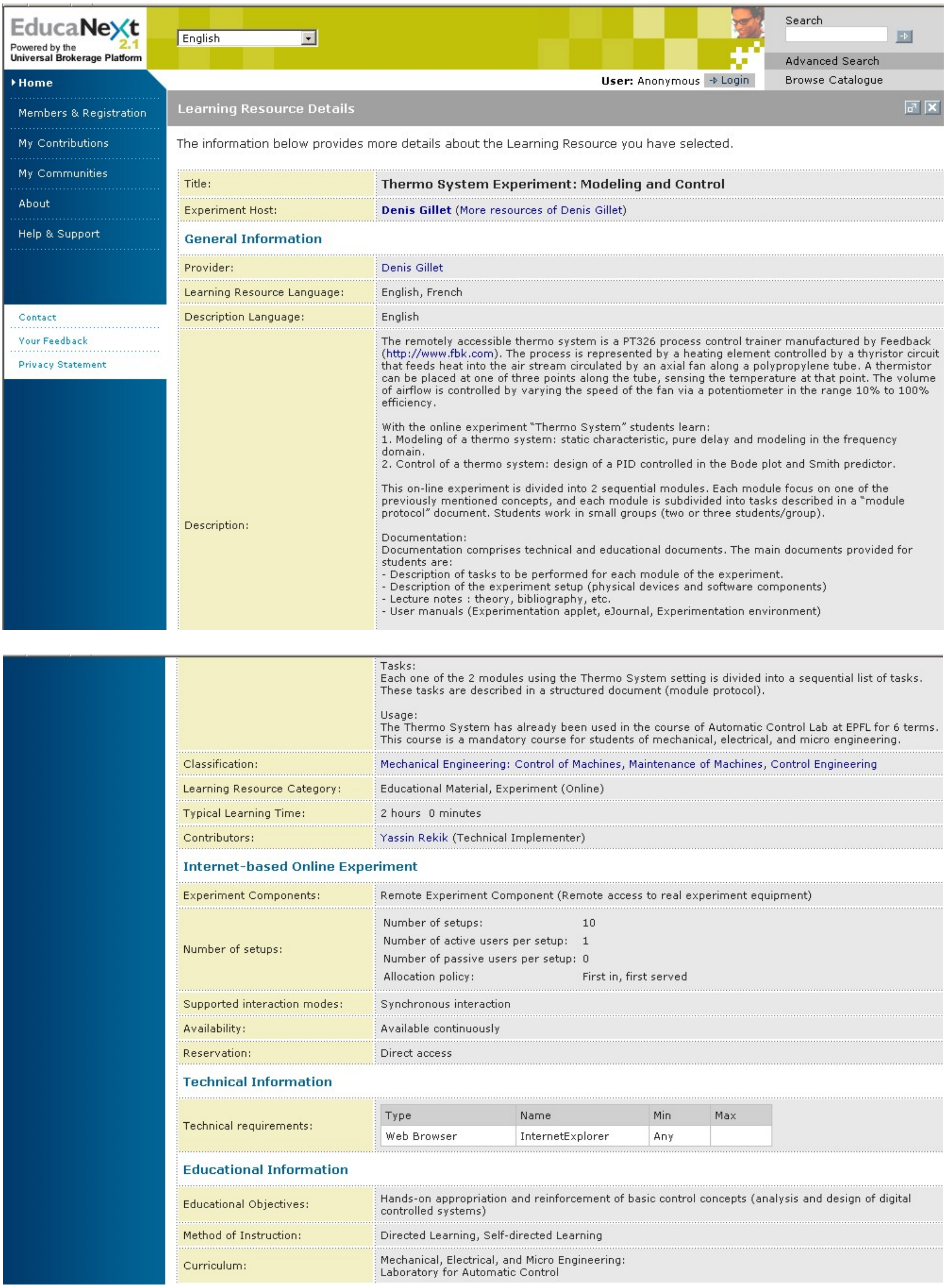
The options are:

- Online Reservation [Link to reservation system] (Reservation is required and can be done through a Web based reservation system. The link to this system is provided.)
- Offline Reservation (Reservation is required and is done by contacting the experiment owner.)
- Stand in Queue (Several users connecting to the experiment at the same time stand in a queue. Typically the usage time is limited to a few minutes and then the current active user is logged out. Then the next user waiting in the queue is given access to the experiment.)
- Direct Access (If no experiment setup is available users will receive a message and have to try again later.)

Attribute Guest access: A guest is a person that works with the experiment for a short time to get an impression of its usefulness. A guest access is an offer by the experiment owner to test the experiment as a guest free of charge. Signing up for guest access should be possible online without manual intervention from the experiment owner. The ProLEARN community strongly advocates the implementation of guest accesses to help broaden the awareness and expend the use of online experiments in education.

- Terms of use: [Text field] (For example: maximum connection time, usage modes for guest.)

Figure 1 shows an example of experiment description using metadata.


EducaNext 2.1
Powered by the Universal Brokerage Platform

English

Search
Advanced Search
Browse Catalogue

User: Anonymous Login

Home
Members & Registration
My Contributions
My Communities
About
Help & Support
Contact
Your Feedback
Privacy Statement

**Learning Resource Details**

The information below provides more details about the Learning Resource you have selected.

| | |
|---|---|
| Title: | **Thermo System Experiment: Modeling and Control** |
| Experiment Host: | **Denis Gillet** (More resources of Denis Gillet) |

**General Information**

| | |
|---|---|
| Provider: | Denis Gillet |
| Learning Resource Language: | English, French |
| Description Language: | English |
| Description: | The remotely accessible thermo system is a PT326 process control trainer manufactured by Feedback (http://www.fbk.com). The process is represented by a heating element controlled by a thyristor circuit that feeds heat into the air stream circulated by an axial fan along a polypropylene tube. A thermistor can be placed at one of three points along the tube, sensing the temperature at that point. The volume of airflow is controlled by varying the speed of the fan via a potentiometer in the range 10% to 100% efficiency.<br><br>With the online experiment "Thermo System" students learn:<br>1. Modeling of a thermo system: static characteristic, pure delay and modeling in the frequency domain.<br>2. Control of a thermo system: design of a PID controlled in the Bode plot and Smith predictor.<br><br>This on-line experiment is divided into 2 sequential modules. Each module focus on one of the previously mentioned concepts, and each module is subdivided into tasks described in a "module protocol" document. Students work in small groups (two or three students/group).<br><br>Documentation:<br>Documentation comprises technical and educational documents. The main documents provided for students are:<br>- Description of tasks to be performed for each module of the experiment.<br>- Description of the experiment setup (physical devices and software components)<br>- Lecture notes : theory, bibliography, etc.<br>- User manuals (Experimentation applet, eJournal, Experimentation environment)<br><br>Tasks:<br>Each one of the 2 modules using the Thermo System setting is divided into a sequential list of tasks. These tasks are described in a structured document (module protocol).<br><br>Usage:<br>The Thermo System has already been used in the course of Automatic Control Lab at EPFL for 6 terms. This course is a mandatory course for students of mechanical, electrical, and micro engineering. |
| Classification: | Mechanical Engineering: Control of Machines, Maintenance of Machines, Control Engineering |
| Learning Resource Category: | Educational Material, Experiment (Online) |
| Typical Learning Time: | 2 hours 0 minutes |
| Contributors: | Yassin Rekik (Technical Implementer) |

**Internet-based Online Experiment**

| | |
|---|---|
| Experiment Components: | Remote Experiment Component (Remote access to real experiment equipment) |
| Number of setups: | Number of setups: 10<br>Number of active users per setup: 1<br>Number of passive users per setup: 0<br>Allocation policy: First in, first served |
| Supported interaction modes: | Synchronous interaction |
| Availability: | Available continuously |
| Reservation: | Direct access |

**Technical Information**

Technical requirements:

| Type | Name | Min | Max |
|---|---|---|---|
| Web Browser | InternetExplorer | Any | |

**Educational Information**

| | |
|---|---|
| Educational Objectives: | Hands-on appropriation and reinforcement of basic control concepts (analysis and design of digital controlled systems) |
| Method of Instruction: | Directed Learning, Self-directed Learning |
| Curriculum: | Mechanical, Electrical, and Micro Engineering:<br>Laboratory for Automatic Control |

**Figure 1. Screen shot of EducaNext Web based catalogue of online experiment descriptions**
**Example entry: Thermo System Experiment - Modeling and Control**

### *C. Content overview*

Good content is the key to success for a knowledge base. There needs to be a sufficient number of online experiment descriptions in the catalogue, so people will invest time to search for experiments there. And only if enough people search in the catalogue experiment owners are motivated to enter new descriptions for their own experiments. As a catalogue was created in the scope of a European project a focus was put on European experiments, but also adds some world class international experiments to the database as well.

Presently the catalogue of online experiments enlists 52 entries, of which 47 can be classified under either of the following classes: science, technology or medicine. The variety of fields within these classes shows that online experiments have a lot of potential in distributed learning (see Figure 2). Some experiments are set up on an interdisciplinary basis, so that they cover more than one discipline.

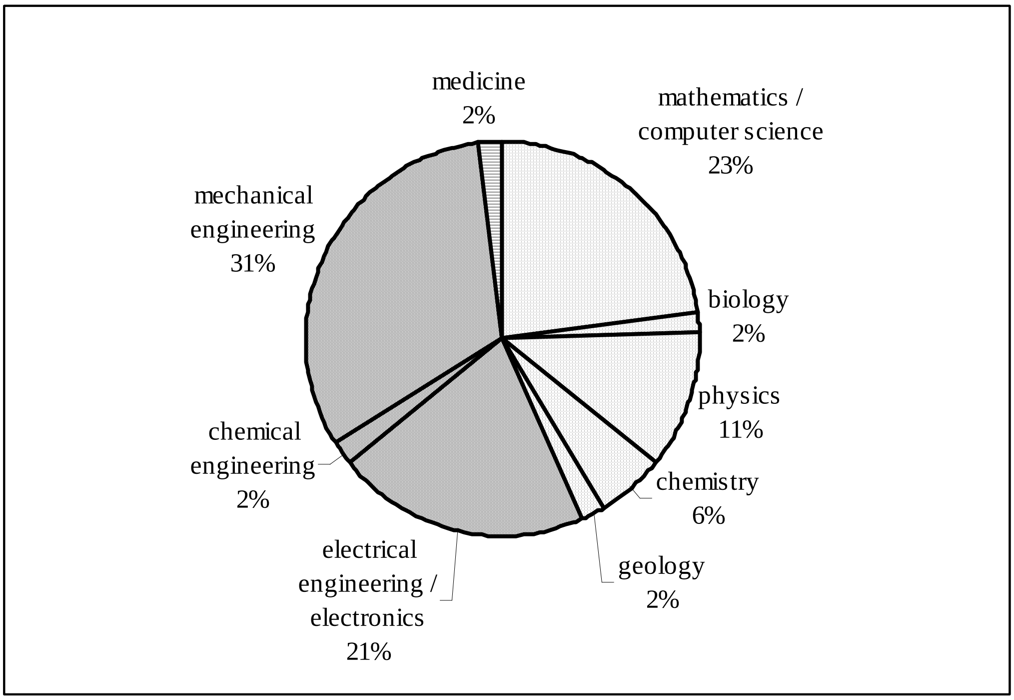



**Figure 2. Classification of Online Experiments (based on EducaNext, December 2006).**

The main areas of remote experiments are situated in mechanical engineering on the technological side and computer science on the scientific side. In general, the objective is to put theoretical knowledge into practice in terms of a simulation (virtual experiment) or a remote respectively local experiment. The main learning method is self-directed learning alone or in groups. In general, the experiments offer more than one setup. Both, synchronous and asynchronous communication is used for interaction. For synchronous laboratory work, on online reservation is needed with some experiments.

## III. SURVEY OF FEATURES AND APPROACHES OF ONLINE EXPERIMENTS

Online experiments (software simulations of real experiments or processes and remotely controlled experiment equipment) enable users to get hands-on experience without the need to leave their workplace to go to a local laboratory. Compared with local experiments, virtual and remote experiments open the potential for flexible learning in time and place, access to a large number of experiments and cost savings through experiment sharing.

In this section an attempt has been undertaken to analyse main technical, educational and methodological features of virtual and remote experiments/laboratories represented in the catalogue. Such an analysis of existing online experiments and laboratories may help educational researchers and lab developers in building new ones.

A study on common requirements specification for a technical framework is a separate task of the ProLEARN working group OE and out of the scope of this paper.

*A. Virtual experiments and labs*

Numerous technological solutions are used to make Web-based simulations more interesting and interactive. These features are realised either at the client side as embedded features or plug-ins for Web browsers, at the server side using different techniques or as a combination of both. The solutions to carry the simulations on Web are among others: Java applets, ActiveX components, VRML virtual worlds and Flash interactive movies.

There are virtual experiments which represent collection of interactive Java applets. In addition, there are some Java-based tools to assist students in making graphs, figures, spreadsheets, etc. An example Java exam interface is also available. Some applets can be additionally downloaded and run offline as a standalone application.

Pedagogical and methodological approaches used for online simulations differ from those used in a local lab. Tutorials, concept tests, design of multiple scenarios of simulations are implemented in several virtual labs.

There are tools to realise Web based simulations able to provide a concrete support to the learning process.

Use of “trial and error” approaches is further common feature of many experiments described in the catalogue.

Many simulations and laboratories in engineering courses via Internet include dynamic components.

One group of online simulations is targeting the replacement of real experiments, while another group is used for the pre-laboratory period in order to better prepare students for real experiments.

Some of Web-based simulations consider the requirements for both main actors involved in the learning process: learner and trainer. These applications have an interface for the trainer or teacher and another for the learner or student.

An application user interface generally includes commands where the user introduces the necessary data (input parameters) for operating the application, along with indicators where the user can visualise the results (output parameters). The user interface of the applications simulating the real process also has this structure. Some applications consist of a front panel (user interface) and a block diagram that represents the application program. The controls (where the user introduces the data) and the indicators (where the user displays the results) constitute the objects of the front panel. Each object of the front panel has its corresponding terminal on the diagram.

Virtual laboratories are often designed as a portal where the users can find several practical assignments on the topics mentioned, practical exercises on those topics, and an engine able to provide marks and advices about the solutions that students propose to those assignments. Thus, the students can upload their assignments solutions, and receive in real-time those marks and advice so they can receive feedback and improve the solutions. For example, in Virtual programming lab [19] the experiment is documented extensively on the Web pages. The documentation is structured as follows:

- usage of the virtual laboratory, including instructions on how to use the lab and how to install the additional components,
- text of programming assignments including requirements, design, implementation notes, tests and frequently asked questions,
- etc.

Some applications allow to modify the experiment and even to design own experiment. Usually it is a special feature of teacher interface. In this way a teacher can better fit his goals or particular student interests. For example, in virtual labs on chemistry the Authoring Tool allows to modify an existing activity or create an entirely new one [20]. This tool allows among others to:

- Choose chemical reagents from the default stockroom or create new ones.
- Select the types of information and instruments available to students.
- Control the level of precision needed for the laboratory techniques, to either allow students to quickly create chemical solutions (as in some forms of homework) or require them to use proper lab techniques (as in a pre-lab activity).
- Write a problem overview and instructions that students can read online or print before they begin.

At any time, it is possible to preview how the assignment will appear to the students. It is also possible for teacher to share his activity and experience with other educators.

*B. Remote experiments and labs*

Thanks to Internet accessibility it is possible to carry out remote experiments with real equipment, i.e. without being physically on site where the equipment is installed. Hence students gain the flexibility of accessing the equipment outside typical laboratory sessions and universities gain the opportunity of using the same equipment.

There are three main aspects to consider when deploying remote experiments as described below.

First, the experiments should be carefully designed to be pedagogically valuable and technically observable at distance. The pedagogical features are usually already adequate if existing local experiments are considered. The technical features encompass dynamics and complexity. For highly dynamic systems, a live video view with a sufficient frame rate should be provided when rendering the experiment behaviour to the users (see Figure 3). For complex systems, a sufficient number of complementary views should be provided. It may include augmented reality and remote control of the orientation and setting of the cameras.

Second, the schemes to access and communicate with the experiment should also be carefully designed. A high level of security is necessary to avoid damages on the experiments and recovery procedures should exist to bring back the experiments in safe states between users or sessions. In that sense, reversible experiments and experiments which do not necessitate row material or human intervention are preferable. Even if many users may access an experiment simultaneously, the typical mode of operation is one-to-one (user-to-experiment) for consistency (a car cannot have two drivers) and interaction reasons (the result of an action should be observable as soon as possible). The chosen communication schemes should support these constraints while relaying on standard protocols and ports to avoid problems with firewalls (which has been one of the main technical bottleneck towards a real spreading of online experiments in the last decade).

Third, the user interface should be interactive enough not to disturb the learning process by delays ore interruptions. It should also integrate computer-supported collaborative learning (CSCL) and data logging features. CSCL features should enable an emulation of the joint activities typically conducted when the experiments are carried out on site. Data logging is important for further off line analysis and reporting activities typically conducted after experiments are completed.


**Figure 3. User Interface of a remote experiment with a live video view of the equipment**

Two different approaches can be considered when deploying remote experiments. The first approach relies on professional packages the educators already use for their day-to-day activities and for local experiments, such as Matlab or LabVIEW. Their Internet functionalities, the Matlab Web Server and the LabVIEW Remote Panels solution respectively, ease in some ways the enabling of remote accesses, but lake convenient features for a real integration in comprehensive learning environments. In addition, they are proprietary and have associated license costs. The second approach relies on standard Web development solutions, such as Java or Flash technologies. This second approach results in longer developments but in better-tuned functionalities.

The complementarities of virtual and remote experiments can be exploited for pedagogical reasons. On one hand, remote experiments can be used to acquire the necessary information to build or to validate simulation models upon which virtual experiments rely. On the other hand, virtual experiments can be used to carry out preparatory or validation work before conducting a real experiment remotely. These two schemes corresponds to the basis of the engineering methodology, thus constituting an additional side learning "product" for the learners.

## IV. Examples of Online Experiments from the Catalogue

In the following three selected examples of virtual and remote experiments and labs developed by different European higher education institutions are described in detail.

### *A. Example of a virtual lab*

A VL described in this section is targeting not only higher flexibility and access by more students but replacement of equipment that is not available or cannot be used for educational purposes.

Iron making process is a good example of complex technological processes and aggregates which cannot be studied integrally either theoretically or experimentally. Work in a local lab usually deals with experiments that simulate separate parts/zones of a real process/aggregate. Construction and operation of physical models that integrally simulate the real aggregates even on a small scale is enormously costly and time consuming, so that it is unrealistic at universities and at the majority of research organisations.

Web-based VL "Ironmaking" developed by RWTH Aachen University is based on online computer simulations and experiments but not limited to them. The VL is a set of multiple synchronous and asynchronous components [21,22]. Virtual simulations are directly linked to theory and support resources (text and reference books, recorded and live lectures, and other interactive and instructive material) [23].

The key component of the VL is the interactive, distributed application "Visual Simulation Model" (VSM) of the Blast Furnace Process (see Figure 4).

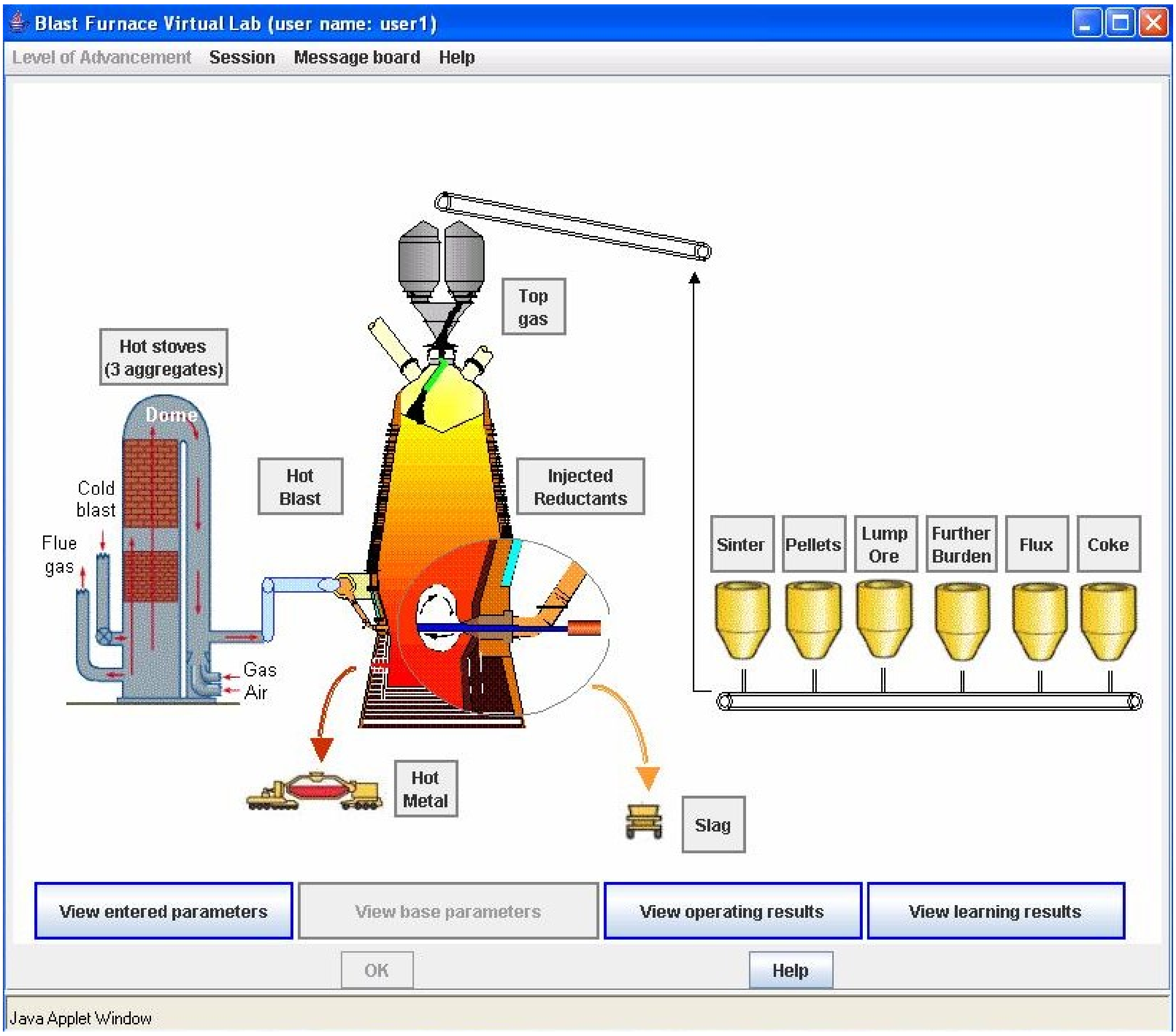



**Figure 4. Screen shot of the VSM user interface**

The simulation model processes *input* values for parameters to generate operating and learning results (Figures 5, 6). The operations of the simulation model are progressively difficult. In the first step values of individual parameters and the list of mandatory parameters are checked. In the second step the combination of individual parameters is verified. In the third step total material and energy flows are examined and corresponding recommendations are given if necessary. The next part of the work using the VSM is the Process Control. Students have the possibility to affect the process results using process control functions. Various modes to achieve this goal are foreseen: change of parameters in the main menu and choice of correcting actions suggested by the model (Figure 7). Before making the decision about control actions, a student has the possibility to forecast change in value of some output parameters using an add-on calculation program. Whenever errors are committed (i.e., wrong or missing values for parameters), penalty points would be incurred and accumulated to the final grade.

The model reflects dynamics of the process (delay in the change of output parameters after conducting the control actions).

The simulated blast furnace process is a link in a chain of metallurgical processes. The simulation model allows the student to investigate related processes (sinter and pellets plants as well as work of heat stoves) by means of connecting sub-models and calculating in this way the expected overall performance.

The VSM enables collaborative work support and interactive tutoring. The remote tutor is equipped with visual front-end software to monitor the activity of the students, answer their questions, and analyse the learning results. Student-tutor and student-student communications are text-based with the use of a message board. Students on geographically dispersed sites can collaboratively ‘charge’ and ‘operate’ the same simulation model and view the results simultaneously. To better analyse students’ work, the tutor can view the computer log of their actions. The VSM software is implemented in Java and therefore able to run on nearly any platform making use of the Remote Method Invocation mechanism for communication via the Internet. The framework of the programme is kept quite general, so that on the one hand the underlying model or the user interface can be safely changed, and on the other hand models of entirely different processes can be easily added and integrated, given the conformity of the programming interface.


Figure 5. Operating results

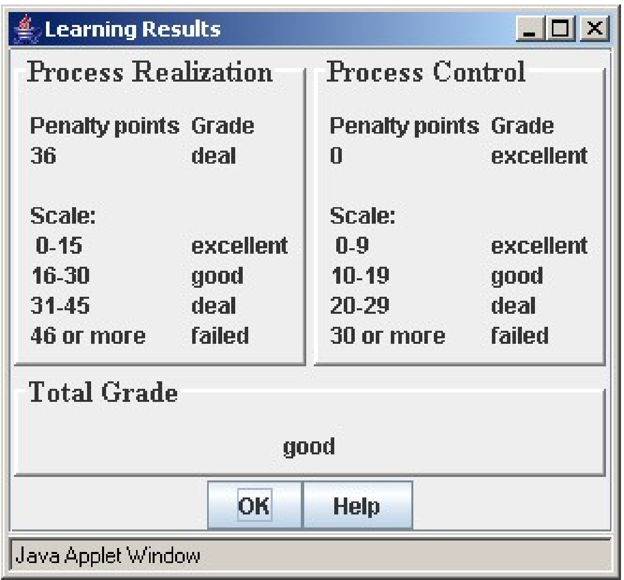



Figure 6. Learning results

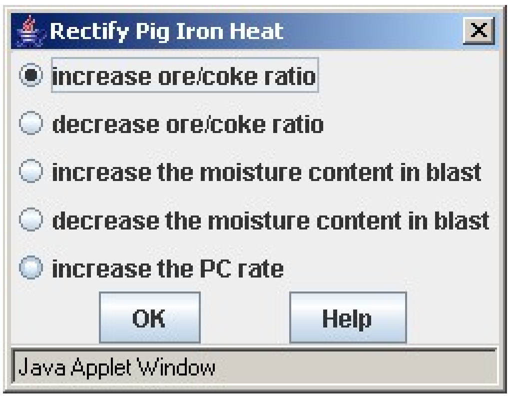



**Figure 7. Suggestions for improvement of the operating results**

*B. Example of a remote experiment*

The following example developed at L3S Research Center is called i-Labs, Internet assisted Laboratories. The objective of this remote experiment is to program, maintain and supervise remote devices aiming at students of electrical and mechanical engineering. The remote experiment can be programmed through a Web based programming environment. It allows editing, storing, compiling, uploading and running of programs. It consists of three areas (Figure 8):

- telepresence area: live video stream of the experiment
- programming area: needed to carry out the task(s) of programming
- communicative area: audio, video and text based communication possibilities for participants and tutors as well as a means for desktop sharing

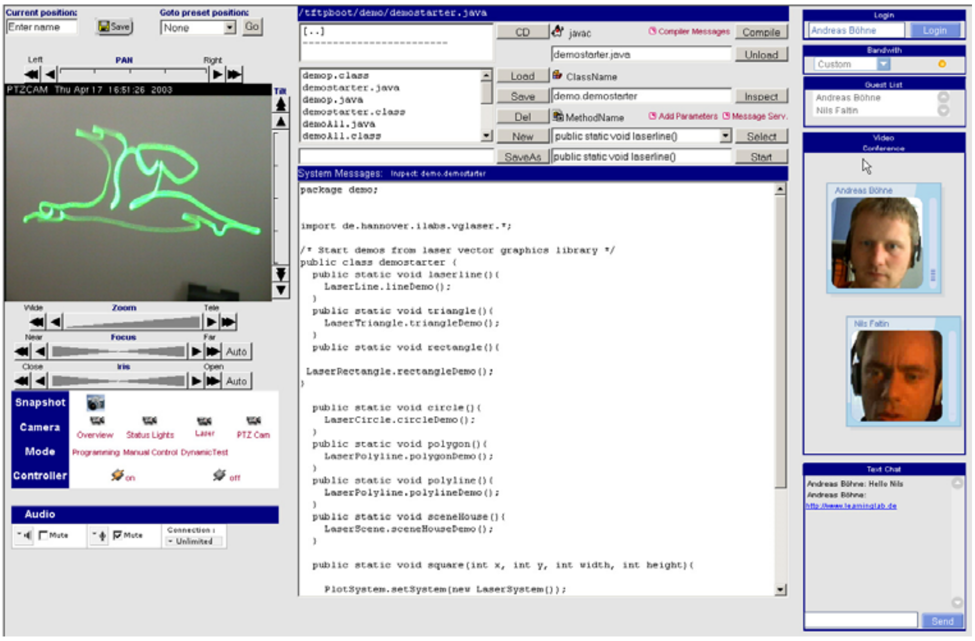


**Figure 8. i-Labs Web interface consisting of different areas**

When working remotely on the experiment, students have to accomplish one or more problem based tasks such as generating a picture on a canvas by a Java controlled laser beam. When group works are carried out online, it is necessary to meet synchronously and get support from a tutor. This way, students get instant help and are able to solve the task problem collaboratively. The tutor does not have to be present at all times but only when needed. The communication area is used for collaborative work. In the telepresence area, the students can instantly see the result of their work and make adjustments. Studies have shown that remote experiments are a sound alternative to face to face experiments [24]. In this setting, it is possible to work in groups where the students are co-located at one location or distributed over several locations. Even though there might be a lack of social presence in the latter case, the tasks can be carried out with the same motivation and quality.

*C. Example of a remote lab exercise*

The remote laboratory exercise “Flow Losses in a Linear Cascade” developed by KTH Stockholm (Figure 9) aims at providing practical training to the students in measuring pressure losses in a linear turbine cascade. Great effort has been put to simulate the real state where a gas turbine is supplied with a flow of high velocity gas passing through it. Here, an air stream (around 2.5 kg/s air mass flow rate) passes through a row of blades representing the linear turbine cascade. The measurement of the pressure of the airflow upstream and downstream of the cascade at various traverse locations gives the pressure losses over the blades.

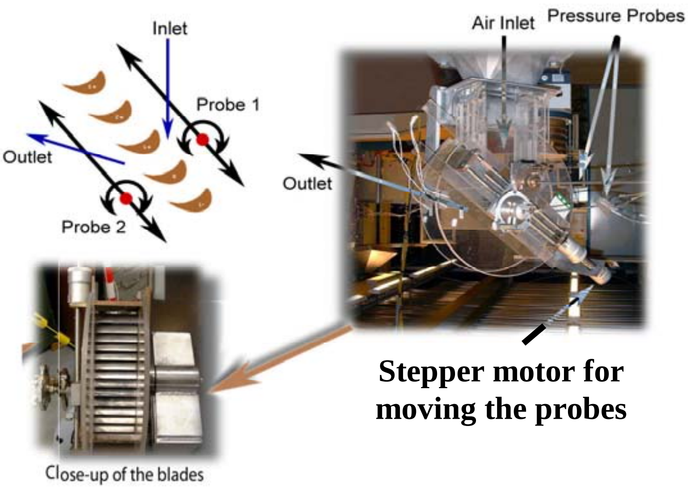



**Figure 9. Flow losses in Linear Cascade facility**

Remote users perform the lab exercise with the graphic user interface shown in Figure 10. This user interface mainly contains two live video streaming windows. Users have the full control of Pan, Tilt and Zoom of the two cameras. It also contains an audio control button so that the users can regulate or mute the sounds. Below the streaming windows there are several sub control panels as described in Figure 10.

The probe sub-control panel consists of two parts: probe rotation and probe positioning. Here, the user can control the probes using incremental and absolute values as well as get information about the position of the probes. Blue bars represent manometers used to align the probes with the airflow.

Chat window permits the users to communicate with the group and share the experience. They also can use chat window to communicate with the lab instructor in the remote lab. The message window displays important information during the lab exercise.

The data logging consists of one altering window that can switch between graph and indicator mode. Indicator mode shows current activity and the graph shows the values of the logged data points. The data points are logged manually by pressing the “Log data” button. User also can delete data points.

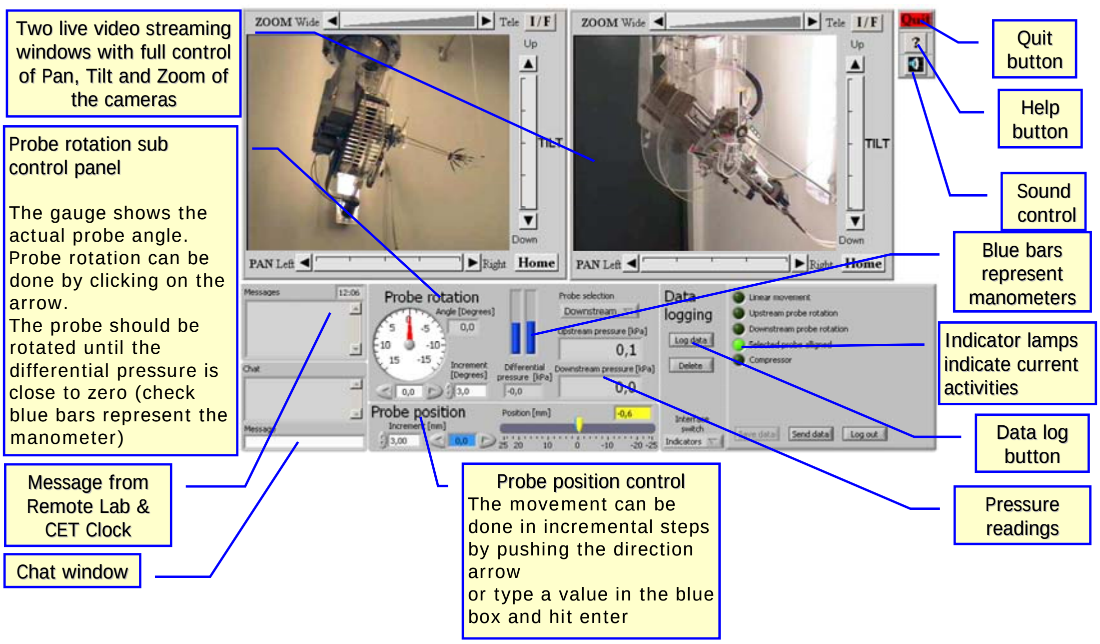



**Figure 10. Remote lab user interface**

## V. Conclusions

Numerous online experiments (both virtual simulations and remote labs), which are of great importance especially for engineering education, have been developed during the last several years.

A Web based catalogue of online experiments descriptions has been created recently to provide an overview of existing online experiments and laboratories and to facilitate their search both for students and educators, as well as to get a quicker start for educational researchers and lab developers in building new ones. It is a kind of an electronic online repository of experiment descriptions, allowing educators, experiment developers and educational researchers to locate online experiments of interest.

The catalogue was set up according to the metadata schema which consists of the standard and additional attributes specified for online experiment as a special kind of learning object. It includes presently more than 50 descriptions of online experiments and is being permanently extended/expanded.

Some typical technical, educational and methodological features of virtual and remote experiments/laboratories represented in the catalogue are identified. It may help the educational researchers and lab developers in building new ones.

One difficulty with online experiments is how to ensure the continuity of operations and accessibility. Once traditional learning material is online it can stay their forever. On the contrary, the presence of an online experiment in a catalogue does not guaranty its availability. Schemes to update and broadcast continuously information regarding the state are then important and will be developed in the future. Relevant indexing in search engines is also a key issue to be tackled.

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