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A Novel Approach to Multilanguage Remote Teaching: Magnetic Measurement Experiment

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Abstract *– A novel approach to electric and electronic measurement teaching has been developed allowing students from different Countries to get in the hand with measurement on real instrumentation, with no need for expensive laboratory instrumentation and personnel. It is shown through a magnetic measurement experiment on multilingual base. Following current European Union efforts to expand newest educational principles to the partner and neighbour Countries, this approach can be used for spreading thriving knowledge economy and life-long learning idea among them thus creating a European education and research area realizable. Developed in the framework of a remotely accessible laboratory developed at the University of Sannio, Italy, experiment allows students to analyse the characteristics of different magnetic materials and the influence of hysteresis phenomena on magnetic and electrical circuits. The experiment includes the interactive verification of the knowledge acquired by the students and can be executed in seven different languages: Croatian, English, French, German, Italian, Romanian, and Spanish.*

Keywords *– measurement teaching, experiment, multilingual, remote laboratory.*

I. INTRODUCTION

Some of the most important aspects of nowadays presented strategic plan of European Union (EU) for 2005-2009 [1] are education reform and research investment strategies. European Community Lisbon Program [2] declares: "*Europe will need to invest more in its young people, education, research and innovation, so that we can provide our society with the assets and outlook to generate wealth and provide security for every citizen*". Some of the most important goals for next few years are creating the European Research Area, development of Internet based education and training as a part of a Lifelong Learning Program and others. Particularly, recognizing the advantages of Internet based facilities several programs, initiatives and projects have been founded by EU Commission (7nth RTD, i2010, the most recent Framework 6, and so on). Due to the wide political and social transformation in East Europe, western Balkan and Mediterranean area, there is the increasing need for new teaching approach similar to European one. European Commission established European Training Foundation (ETF) which mission is to assist partner Countries in developing quality education and training systems and in putting them into practice [3]. Each year, the ETF work program is structured around a series of projects (TEMPUS, SEE, MEDA, EECA, etc.) which take place in the partner Countries to facilitate the reform of vocational education and training and employment systems. Approach proposed in this paper could be used to spread this novel and accepted education approach in mentioned Countries.

When speaking about education in technical areas practical experience is a step of crucial significance when comes to placing a theoretical knowledge in work. Especially in teaching electric and electronic measurement topics, this kind of experience should be given to the learners trough laboratory work. However, due to expensive equipment, necessity for repeating the same experiment many times (because of a big number of students) and insufficient number of qualified teaching personnel, electric and electronic laboratories for didactic purposes are difficult to set-up. Moreover, some faculties across different Countries are unable to deal with mentioned problems mainly due to the lack of financial support. Considering all mentioned, University of Sannio in Benevento, Italy, is currently developing common projects with Croatia [4], Greece, Slovakia, and Ukraine [5]. The necessity of a common education system based on the Web is a main topic for the European universities. A thematic network has been realized with this aim [6].

Regarding remote measurement laboratory as a Distributed Measurement System (DMS) with some simplifications deriving from the specific requisites of distance learning a distance learning laboratory has been developed at the University of Sannio, the Remote Laboratory Distributed on Geographical Network LA.DI.RE. "G.Savastano" *(http://www.misureremote.unisannio.it)* [7-10]. It includes the features of a complete Learning Management System (LMS) with experiments on actual electronic measurement instrumentation, and is currently under test.

Some experiments are already available in the following fields: digital signal processing, use of oscilloscopes, arbitrary waveform generators, counters, testing of data converters, testing of telecommunication devices. They have been developed in Italian language and currently don't include an adequate feedback system validating the quality of the achieved experience (although LMS has a testing module for examination of transferred knowledge). In order to implement new multilingual approach and extend the functions of the laboratory to electric measurement courses, a new experiment was realized for practicing with magnetic measurements. This experiment, described in the next sections, gives to the undergraduate student opportunity of deeper understanding of dynamic hysteresis phenomena and magnetic circuit principles, which are a crucial step for start of work in mentioned areas. The experiment includes an interactive feedback system for verifying the results achieved by the students and, moreover, it is the first experiment available in seven languages. These new features will enable communication and the knowledge transfer among teachers and students coming from different countries. Currently, the research team is working on international distribution of LA.DI.RE. "G.Savastano", with goal to enable international research corporation and transfer of European educational principles over Western Balkan area and forward.

II. THE REMOTE LABORATORY

The World Wide Web through past years became a channel that enables learners to get in touch with measurement instrumentation worldwide by requiring a minimal connection cost and allowing the realization of numerous flexible and customized measurement solutions. From the didactic point of view, currently, there are four main approaches that are followed for the remote teaching of measurement science: (i) web based lectures and seminars mainly directed to professionals that want to reduce the start-up time for a new application [10], (ii) web based delivery of teaching material for University courses, including slides of the lessons and exercises [11,12], (iii) simulation of actual experiments that are to be executed either remotely or on the user's PC [13,14], and (iv) more rarely remotely accessible laboratories where the students can access the actual instrumentation trough a web page [15,16].

The realised remote laboratory platform, LADIRE "G. Savastano" has the main goal of enabling the distance learning in the field of electric and electronic measurement. The students are provided with remotely accessible experiments on real measurement instrumentation by using a common web browser only [8,9]. Three user profiles have been created in its platform: *student*, *teacher* and *administrator*. (i) *Experiment Visualization* allows the student to display on his own computer a laboratory experiment typically held by the course teacher; (ii) *Experiment Control* allows the remote student to perform a pre-defined experiment, controlling effectively one or more actual measurement instruments; (iii) *Experiment Creation* allows the student to remotely create a new experiment.

The core component of the overall distributed architecture is an improved LMS, chosen on the basis of its capability of managing and building Web-based courses according to Aviation Industries Computer-based training Committee (AICC) [16], Instructional Management Systems (IMS) [17] and Advanced Distributed Learning [18] specifications. This platform delivers user authentication and management as well as the tracking of user learning process. The remote laboratory is currently organized according to a Web-based and multi-tier distributed architecture [8,9] showed on Fig.1. The *presentation-tier*, that manages the experiment on client-side, is based on standard Web browsers, with no need of specific software components. The server-side logic, composing the *middle-tier*, is distributed on the following servers: (i) a *LMS*, executed on a central server, called *Laboratory Portal*. The LMS interfaces to the users through a Web Server that is hosted on the same machine; (ii) the *Laboratory Server* (LS), used to interface each laboratory with the rest of the system. It delivers the access to the laboratory equipment, and (iii) the *Measurement Server* (MS), a server located in a laboratory that enables the interactions with one or more instruments. Each MS is physically connected to a set of instruments. The server-side software component used to control the electronic instruments is LabVIEW^{TM}, developed by National Instruments.

2.1 Remote management of experiments

There are numerous solutions which can be used for remote control of measurement devices or, particularly, measurement experiments. LabVIEW is one of today most recognised and used programming tools for development of measurement software, some of the best solutions are proprietary solutions of the National Instruments ^{TM}. The first one consists in realizing two Virtual Instruments (VIs), one on the client side and the other on the server side communicating via the TCP/IP protocol or the proprietary *Datasocket* technology. The second one relies on LabVIEW web server that gives the possibility of viewing an image of VI running on the server machine, while for accessing and controlling it client should have LabVIEW runtime environment installed. Several solutions have also been proposed implementing a specific client-server couple using object oriented programming languages, instead of using LabVIEW.

For the purposes of the LADIRE "G.Savastano" realization, the first solution has been discarded as it requires a licensed LabVIEW installed on the student's PC while second solution requires the long download of a heavy plug-in from National Instruments to be installed on the client side. Second solution also does not run smoothly for demanding experiments like the one proposed in this paper.

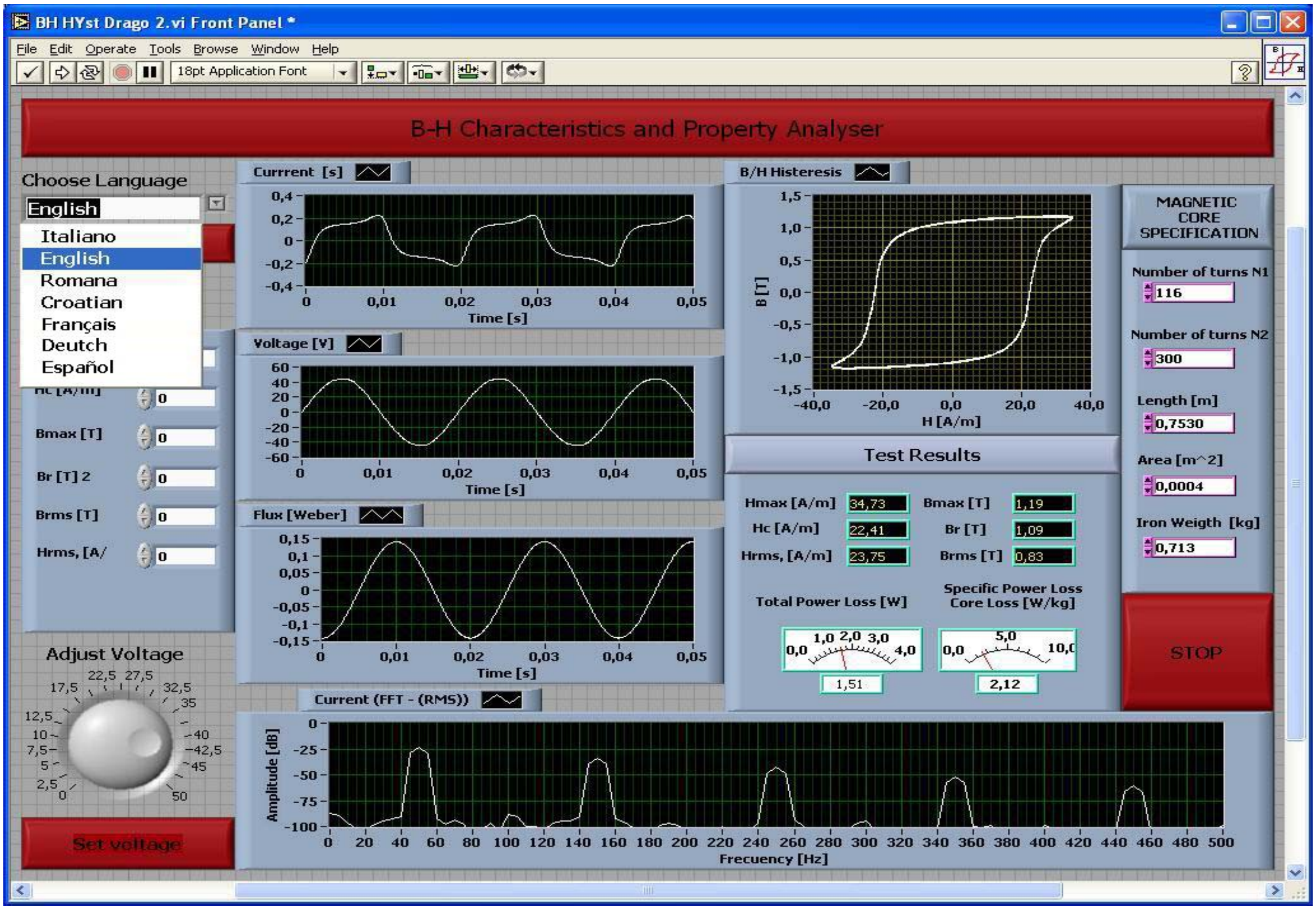
The third solution as well as specific client-server structures has the following advantages: (i) high efficiency from the bandwidth occupation point of view, (ii) light clients that don't require specific plug-ins, and (iii) high portability, when Java-based technologies are used on the client side. Their main disadvantage is the limited reusability of already developed experiments and the necessity of developing new versions of existing VIs, too. In the proposed approach, those problems were successfully solved. Thin-client paradigm splits the presentation layer between client and server. The presentation logic runs on the server, while the thin client has the only task of showing a Graphical User Interface (GUI) that often reproduces the server desktop. This approach gives the possibility of providing remote access to any application, written in whichever language, running locally on the server machine and requiring only an Internet browser on the client side.

Many implementations of the thin client paradigm have been proposed by researchers and deployed commercially. The thin-client platforms that have been evaluated are: Remote Desktop Protocol (RDP), Independent Computing Architecture (ICA), X-Window and Virtual Network Computing (VNC). Those platforms were evaluated in [19] and the RDP protocol was chosen, for its low cost with respect to ICA, and higher efficiency with respect to X-Window and VNC. RDP is a proprietary protocol of Microsoft, and allows direct connection to the Windows server. It supports different mechanisms to reduce the amount of transmitted data (compression, cashing of bitmaps in RAM), which is very important for applications that use a large amount of bitmaps. Starting from ProperJava RDP client, a specific client Applet has been developed and described in [19], the *LaboratoryApplet*. This RDP client extends the solution of ProperJavaRDP and improves the communication performances by adding some functionality such as: *compression* of transmitted data, selection of the *cache dimension* on client side, selection of *load balancing* option which enables choosing the least-loaded server. The efficiency of the developed solution has been confirmed by comparative bandwidth occupation measurements, where the *LaboratoryApplet* gave the best results.

III. MAGNETIC MEASUREMENT EXPERIMENT

The experiment concept

The graphical user interface of developed experiment is shown on Fig.2.The developed experiment is designed as a



Hc [A/m] 0
Bmax [T] 0
Br [T] 2 0
Brms [T] 0
Hrms, [A/ 0

Hmax [A/m] 34,73
Hc [A/m] 22,41
Hrms, [A/m] 23,75
Bmax [T] 1,19
Br [T] 1,09
Brms [T] 0,83
Total Power Loss [W] 1,51
Specific Power Loss Core Loss [W/kg] 2,12

Number of turns N1 116
Number of turns N2 300
Length [m] 0,7530
Area [m^2] 0,0004
Iron Weigth [kg] 0,713

Fig.2. Graphical user interface of the developed instrument (Front panel).

relevant improvement to the courses and lectures regarding electromagnetism and magnetic measurement topics. It gives to the student opportunity of deeper understanding magnetic characteristics of the different magnetic materials. Moreover, it is the first in the LADIRE "G.Savastano" project giving the possibility of recording the efficacy of the teaching method by means of a feedback system. LMS system allows testing of knowledge adopted by the students, but like most of the other developed platforms for remote laboratories it can not be able to test the actual work of the student or the experience he got by executing an experiment. Developed experiment, on contrary, requires from student to observe measurement data displayed on front panel, to extract measurement data out of the plots and to actually calculate or estimate required values. This requirement empowered with availability to adjust load of DUT allows him/her to actively cooperate in execution of experiment. Data estimated by the student is in real time compared to the values calculated by software itself and only if they fill in allowed range of each value, experiment can be finished. By means of the LMS the student is also provided with documentation including: (i) a theoretical background, (ii) hardware and circuit descriptions, and (iii) a user guide. Therefore, before starting the experiment, student should have good understanding of the principles of magnetic circuits. During the practical phase student will study hysteresis phenomena and how changes in magnetic circuit affect the BH curve. After performing this experiment the student should be able on his/her own to examine hysteresis characteristic and estimate its critical values and the uncertainty of measurement data. Experiment is made with two different magnetic materials – a soft and a hard one. This is an important issue for understanding the wide range of currents to be applied to magnetically saturate different magnetic materials. Student has to perform measurements on both of them and compare the results.

3.2 The experiment hardware

The experiment hardware (Fig.3) consists of a programmable source (RT) with separation transformer (T), a device under test (DUT), sensors and a personal computer with data acquisition board. A current sensor (resistor 0,7 Ω) measures the current through the main coil (MC, primary) which enables to compute magnetic field (H) while the voltage sensor (couple of resistors performing a voltage partition) measures inducted voltage on the search coil (SC, secondary) which enables us to compute magnetic induction (B) using the relations:

$$H(t) = \frac{N_1}{l_{av}} \cdot i_1(t) \tag{1}$$

$$B(t) = \frac{-1}{N_2 \cdot S} \int u_2(t)dt \tag{2}$$

where N_1 and N_2 are the number of the windings of the main and the search coil, l_{av} is the average length of the magnetic core, S is the section of the magnetic core, $i_1(t)$ is the main coil current and $u_2(t)$ is inducted voltage on search coil.

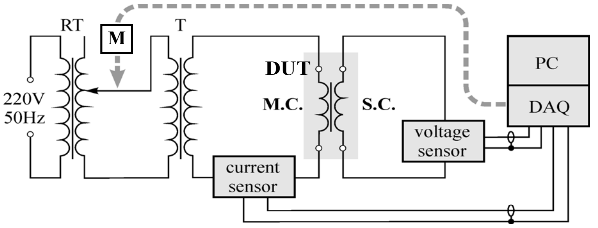


Fig.3. The magnetic measurement experiment schematic.

Device under test (DUT) consists of a metal toroid as ferromagnetic core with primary and secondary coils wrapped around it. A programmable source is composed of a variable transformer (RT), controlled by a data acquisition board (DAQ) and a step motor (M), and a separation transformer (T) which supplies the main coil with a sinusoidal voltage. Due to magnetic saturation phenomenon the current on MC will be greatly distorted (Fig.2). Because of this, output impedance of the programmable source must be very low or this current will produce non-sinusoidal voltage on the source's inner impedance resulting in a non-sinusoidal voltage applied on the DUT. A programmable, low impedance source with a suitable range of supply voltages and currents is a very expensive solution, requiring an additional GPIB card on measurement server. The solution implemented and shown in Fig.3 is therefore a much cheaper and acceptable solution. By using a simple driving circuitry, the step motor has been controlled by means of the same DAQ card that is used for measuring the sensors outputs, a National Instruments PCI-6024E. Although this kind of programmable source is not a very precise one, it is adequate for the experiment purpose because the precision of the applied voltage amplitude doesn't affect the accuracy of the experiment results. The student, in fact, has only to set the source voltage big enough to magnetically saturate the DUT. Variable transformer is separated from the DUT with a separation transformer that additionally reduces voltage and greatens the sensitivity of the programmable source. Programmable source enables student to change the load of magnetic material resulting in a change of the supply current spectrum, the shape and the area of magnetic hysteresis loop representing the power losses.

3.3 Execution of the experiment

The developed GUI shows the waveforms of the acquired signals, the current spectrum, the magnetic flux and the BH hysteresis plot (Fig.2). It also computes (for the adjusted voltage supply) maximum and RMS value of magnetic field and magnetic induction (H_{max}, H_{RMS}, B_{max}, B_{RMS}), coercive force H_c and remnant magnetism B_r and total and specific power losses in the tested magnetic material.

At the beginning of the experiment, student is asked to adjust the programmable source to supply the MC with a voltage that will magnetically saturate the ferromagnetic core. Doing this he/she is able to observe the changes in the given plots and to get practice in determining the point of magnetic saturation. Execution of experiment is continued with source adjusted to mentioned value. During the experiment the student, on the base of the displayed information, has to determine and to read out the critical data from the plots: maximum residual induction (retentivity) (B_r) and maximum coercive force (H_c), the material's saturation flux density, and to try to appraise the area of hysteresis which represents power losses in the material. After that he/she is asked to put the results in a form provided on the left side of the GUI. The VI verifies that the provided results are in a given range of the actual values (calculated programmatically for the adjusted supply voltage). If the check is passed, the real data is shown on the front panel (until that point this data are hidden). Finally, learner is asked to comment mistakes that he/she has made in the calculations.

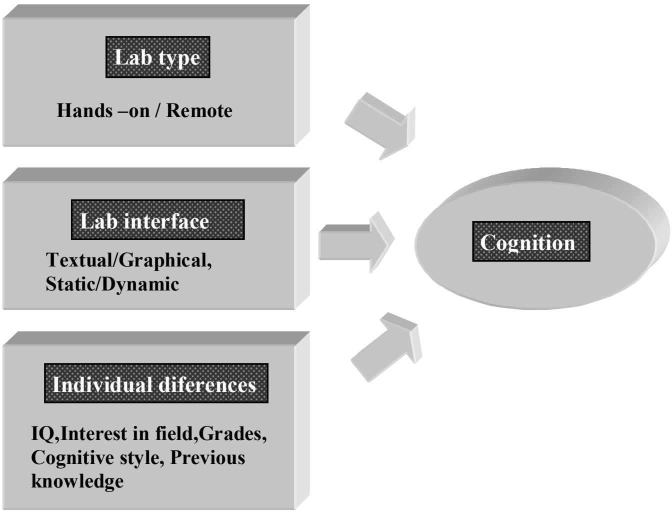


Fig. 4. Model of experiment effectiveness testing.

3.4 Experiment effectiveness testing

Testing the effectiveness of an experiment and student's reaction to it is a very complex and demanding task because things like understanding of essence, feeling for certain measurement and response to coincidental influencing factors can hardly be measured. Some papers suggest testing of student's understanding of experiment concepts (laboratory and test results) as the measure of cognition. This is true only when the goal of the experiment is to give to the student strictly defined and testable knowledge or understanding. Testing of experiment whose goal is giving other, less self-defining but not less important experience and understanding could not be tested this way. Example for this are experiments with goal to introduce a student to certain measurement equipment or general, usually basic problems in setting up certain measurement system. Since the goals of the Magnetic Measurement Experiment are defined and measurable, we were able to test it as prototype for this type of experiments. Influencing factors that could be computed were taken into account as shown in Fig.4. Group of students was chosen to do Magnetic Measurements Experiment after a week of lectures on the subject, executing both: remote and classical (hands-on) experiment. The given tasks were the same, but with different materials: soft and a hard one. After finishing work on one type of experiment, students were asked to answer to control questions and then switch the type of experiment they were executing. When both types of experiments was done, students were asked to fill in the questionnaire. They were asked to rate their opinion about certain advantages of remote and hands-on experiment, as well as the supremacy one over another. Their understanding of the topic was tested in 3 ways: preparation for the experiment, previous knowledge and some crucial understandings that should be gained through experiment. Control questions allowed us to test effectiveness of experiment that was executed first and to test differences in knowledge transfer, while questionnaire after both experiments executed allowed us to compare directly their opinion about the differences of remote versus hands-on experiment. Result of the test showed that for the major part of the students there were no big differences in transferred knowledge or experience gained. Although a classic experiment gave wider insight in measurement giving them an opportunity of experiencing typical errors while assembling the experiment, there were no significant differences shown in transfer of specific knowledge for which the experiment was originally designed. Results of testing showed also that 72% of the tested students were considering remote experiment same or more effective than hands-on (Fig.5).

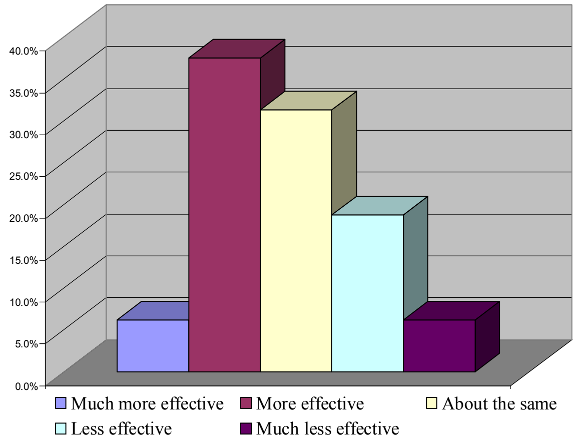


Fig.5. Effectiveness of the remote experiment comparing to classical experiment (hands–on).

Highly rated was low setup time for remote experiment and convenience in access. Some correlation was shown saying that highly interested students are more interested in hands-on experiment because of showing real conditions and problems. Control of the learning process of the students and the obtained examination results was analyzed and it was shown that no significant correlation could be found in knowledge gaining and the type of experiment executed.

Live camera support has been developed and it is currently under test. It will allow students to have stronger feeling of immersion and even "telepresence" in the laboratory. Although live camera requires higher bandwidth available, camera support is necessary for certain experiments and helpful add-on for others. A new experiment allowing students to create their own magnetic measurement VI using available hardware is currently under construction. Future job to be done is to implement measurement of static hysteresis or even a source with a remotely adjustable frequency which would allow students to see the influence of frequency on the behaviour of tested magnetic material.

IV. CONCLUSIONS

The paper presents the work done to extend the features of the project LADIRE "G. Savastano" to the academic circles of East Europe, western Balkan and Mediterranean area. The proposed approach follows EU efforts to implement internal Lifelong Learning Program and influence educational systems of partner and neighbour countries of EU while helping them to overcome problems with their own educational system and lack of resources. The effectiveness of experiment has been tested and results obtained showed that remote experiment can be used as adequate substitution for the classical laboratory experiment, with a lot of advantages considering convenience in access and execution scheduling time. Developed experiment gives the possibility of achieving practical experience on magnetic measurements, while multilingual approach gives the access to such facility to the students coming from different countries. Moreover, the idea of interactively controlled transfer of knowledge and experience gives a new dimension to the remote experiments enabling them to be executed without supervising necessity.

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