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REMOTE VERSUS CLASSICAL LABORATORY IN ELECTRONIC MEASUREMENTS TEACHING - EFFECTIVENESS TESTING

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Abstract: Considering importance of practical experience as a crucial step in effective transfer of knowledge to learner in electric measurements and other technical fields, paper caries out research results of effectiveness testing on remote laboratory developed at University of Sannio, Italy. Although remote laboratories are spreading among universities and educational institutions very fast because of their advantages in setup, price and accessibility actual effectiveness of this laboratories comparing to classical is still unknown. Two groups of students of the electric and electronic measurement courses have been chosen to test the effectiveness of remote laboratory comparing to classical one through specially designed experiment. They were executing both, hands-on and remote experiment. Obtained examination results and the learning process of those students have been analyzed and compared with those obtained by group of students of traditional teaching. Some surveys has also be carried out in order to obtain a feedback on effective usability, benefits and helpfulness of the remote measurement laboratory, but also it's weakness and issues to be improved or investigated in the future.

Keywords: remote, laboratory, education

1. INTRODUCTION

Importance of the practical experience with instrumentation in electrical measurements and other technical branches is a well known fact for every engineer when it comes to putting a theoretical knowledge in work. Because of that effective transfer of knowledge should contain much more than just well organized transfer of set of theoretical understandings. Observation, investigation, experimentation and measurements are the crucial steps that made science what it is today. Process of creating scientists and engineers should be empowered with opportunities to cope the real problems, to gain information that is unfamiliar to them, to explain phenomena, and to solve problems. This is especially true in the teaching of electric and electronic measurement topics, where this kind of experience should be given to the students through laboratory work. But because of 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. A lot of papers and resources suggest use of simulations of actual laboratories [1, 2] which should be solution for the above mentioned problems. But without of confrontation with real instruments with all the influencing factors and the uncertainties we cannot provide good replacement for the hands-on laboratories. Fast development of internet had the great influence on the measurement related tasks and the measurement teaching problems, enabling us to get in touch with measurement resources worldwide and realize number of flexible and customized measurement solutions. The best that we can accomplish using modern technologies are remote laboratories.

In past decade a lot of work has been done in the development of Distributed Measurement Systems (DMS). If we regard to remote laboratories as DMS some simplification can be done by analyzing the specific problem of remote teaching. Following that approach a distance learning laboratory, including the features of a complete Learning Management System (LMS) and some experiments on electronic instrumentation, has been developed at the University of Sannio in Benevento, Italy [3, 4, and 5] and is currently under test. A web based platform for distance learning on electrical measurement course is currently under construction at the Faculty of electrical engineering and computing in Zagreb [6]. Those two faculties also developed a network of remote laboratories with other countries, trying to collect knowledge, a big number of remote measurement solutions and develop common research activity and to enrich European universities with new opportunities and novel approach to knowledge transfer.

2. THE REMOTE LABORATORY

2.1 The laboratory platform

The realized remote laboratory platform 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 [7], with no need for specific software components. Three user profiles have been created in its platform: *student*, *teacher* and *administrator*. The student has access to the following services: (i) *Experiment Visualization* allows the student to display on his own computer a laboratory experiment typically hold 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 main component of the overall distributed architecture is an improved LMS, chosen because of it's capability of managing and building Web-based courses according to Aviation Industries Computer-based training Committee (AICC) [8], Instructional Management Systems (IMS) [9] and Advanced Distributed Learning [10] specifications. This platform delivers user authentication and management as well as the tracking of user learning process. Block diagram of remote laboratory system structure is shown on the Figure1. *Presentation tier* is based on the thin-client paradigm and it has been adopted for realizing the remote

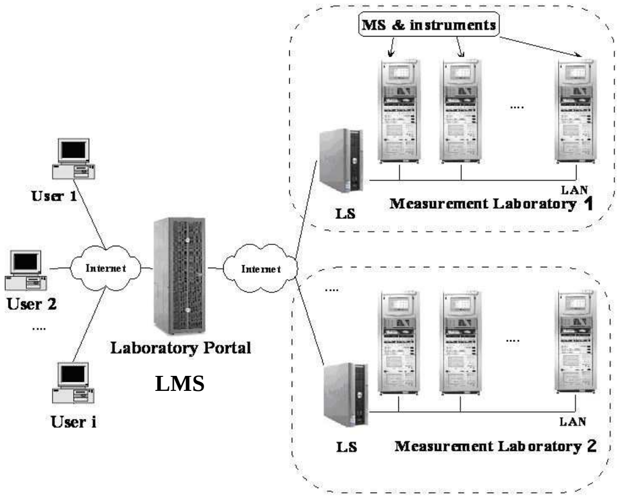

Figure 1. The Web-based remote measurement laboratory components.

access to Virtual instruments (VIs). Using Java version of Remote Desktop Protocol (RDP) *ProperJavaRDP* a new thin client solution was implemented and tested. So called *LaboratoryApplet* has been specially designed and tested in comparison with other possible solutions. Hence *LaboratoryApplet* included advanced caching algorithms, variable cache dimension and higher compression than usual RDP it gave the best results in bandwidth occupation measurement. Java ensured system portability and usability while optimization enabled reduction of the bandwidth occupation and improved the user interaction with experiment.

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™, developed by National Instruments.

2.2 The experiment

Choosing the adequate experiment for this kind of testing is a very tricky but very important part of testing lacks and advantages of the remote laboratory. Not every remote experiment can be good substitution for hands-on experiment neither every experiment can be implemented remotely. It was shown that only when presentation and analysis of the measurement data can be computer supported or experiments tends to be computer oriented, remote laboratories can be of good use. On contrary, in the experiments where students should learn more about actual connecting the hardware or certain problems in experiment setup in real conditions remote experiments will be a poor replacement. (Typical examples are experiments executed on first year of undergraduate studies, where students are facing the basic measurement equipment for the first time). Magnetic measurement experiment developed by authors was considered very appropriate for testing the characteristics of remote laboratory. It was made in two different ways: hands-on and remotely. Both of experiments required from students to calculate and set the load of device under test (magnetic core), to observe measurement data displayed on oscilloscope (or monitor) and to extract measurement data out of the plots and to calculate or estimate required values. Since the goal of experiment, structure and provided data was the same in both cases, we were able to record differences between them and differences in student's reaction on it.

The developed experiment is designed as a relevant improvement to the courses and lectures regarding electromagnetism and magnetic measurement topics. Front panel of the experiment is shown on Figure 2. It gives to the student opportunity of deeper understanding magnetic characteristics of different magnetic materials. 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. 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.

The developed GUI shows the waveforms of the acquired signals, the current spectrum, the magnetic flux and a BH hysteresis plot (Fig.2). It also computes all of the values which are to be used in further execution of the experiment. At the beginning of the experiment, student is asked to adjust the programmable source to supply the DUT 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. After that he/she is asked to compute the results and put them 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. This feature is giving us the possibility of recording the efficacy of the teaching method by means of a feedback system.

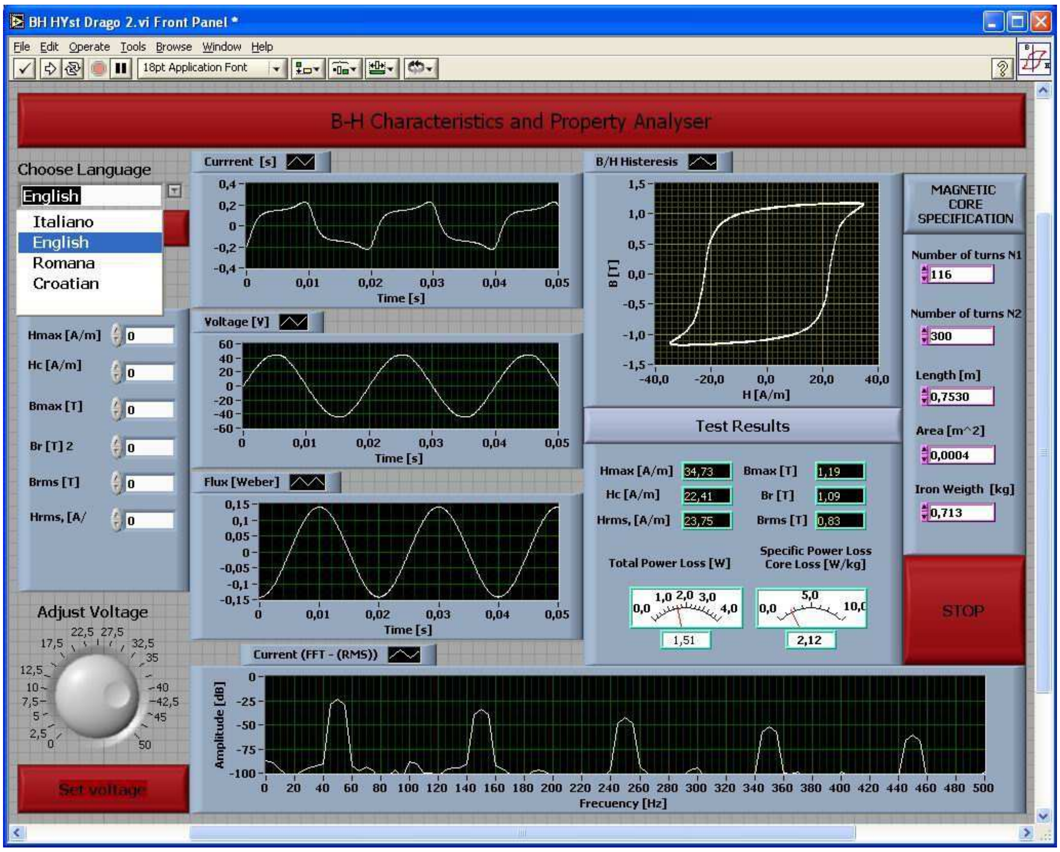

Figure 2. Graphical user interface of the developed instrument (GUI).

3. TESTING METHODE

3.1 Analysis of influencing factors

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 [11] suggest testing of student's understanding of experiment concepts (laboratory and test results) as the measure of cognition. This approach could only be used in cases where the goal of the experiment is to give to the student strictly defined and testable knowledge or understanding. Testing of experiments whose goal is giving others, less self-defining but not less important experiences and understandings could be tested only trough practical tests, which results can be hardly estimated. Influencing factors that we decided to take in account was on the basis of ours but also previous surveys [11]. They are shown in Figure 3.

1) Type of the laboratory: Remote laboratory is not the only one that should be tested when speaking about transfer of experience to the learners. Hands-on laboratory is not perfect, it was until past few years the only one choice that people had. Although hands-on laboratory provide real apparatus, real conditions and problems it is important to understand that it doesn't automatically give optimal learning environment. To solve this problem, a group of students was asked to execute hands-on version of experiment, while other group was asked to execute remote version of the same experiment or other experiment. After the execution of experiment results of their examinations and their opinion about certain aspects of laboratories were compared and statistically analysed.

2) Laboratory interface was also shown as a crucial factor influencing effectiveness of the remote but also hands-on laboratory. Even more, it is very important that experiment enables students in doing two things. First, experiment must give them opportunity to face the raw data and real world conditions and influencing factors (unlike simulations in virtual laboratories), and second it must give them good graphical presentation of measurement data for further analysis. A big number of nowadays presented remote or virtual laboratories often represent unprofessional attempts to solve problem of unavailability of certain equipment to the learners. Undefined goals and lack of

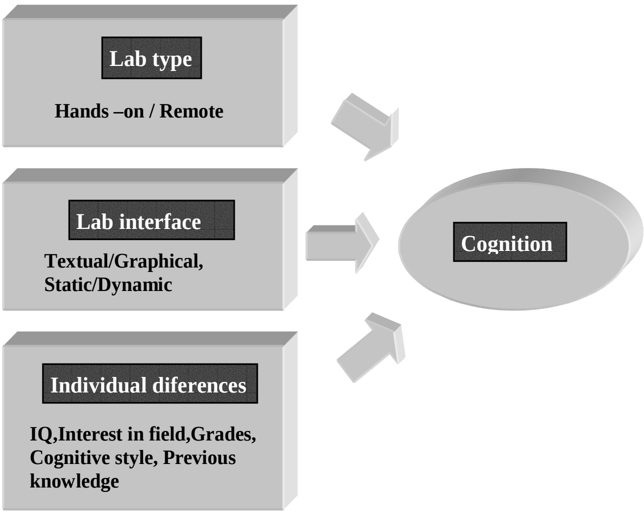

Figure 1. Model of experiment effectiveness testing

standardization in the field enabled even poor solutions to be considered as good and appropriate.

3) Individual differences are third group of influencing factors that we adopted in our model. Results of the pre testing showed that personal differences like previous knowledge, motivation and interest for the topic can influence hardly on transfer of knowledge. Even more, low motivation and lack of interest in the experiment was the main obstacle in effective knowledge transfer to the student influencing hardly both, remote and hands-on laboratories. Some papers suggested influence of person's cognitive style (visual, aural, read/write and kinesthetic) and personal grades or IQ on certain aspects of knowledge transfer through remote laboratory. Their testing results showed light correlation between mentioned, but it was considered marginal and not fully investigated [11]. It must be clear that students with higher grades gave better results than students with lover grades, but this was expected and it is considered normal. Fact that better students will learn more says nothing about effectiveness of laboratory, it says about effectiveness of the student. Also there was no indication that one type of the students learn more effectively than others (giving better results than expected for them considering their grades). Detailed survey of this potential problem would require expertise in areas beyond our work and interest, and it would require different education styles which are not supported in current education system.

2.2 Survey procedure

Two groups of student were chosen for testing of remote laboratory. First group was a pilot group of students asked to do Magnetic measurements experiment after a week of lectures on the subject. Half of them were doing hands-on experiment, while others were executing experiment remotely. 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. After answering to control questions of knowledge, two parts of group switched the type of experiment. When each one of them was finished executing hands-on experiment 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. Cognitive style of students was also tested with standard VARK questionnaire, to find possible correlations. Pilot testing allow us to make necessary changes in survey, to focus on most important issues, to abandon some questions and adopt another. Second group was consisted of 70 students who executed Magnetic measurements as one in series of 16 experiments. Results from the hands-on laboratory were compared with the results from classical laboratory. Their lab reports and gained knowledge where tested and they where asked to compare certain aspects of remote and hands-on laboratories.

2.2 Results

One of the main questions for the students was to rate the effectiveness of the remote laboratory comparing to the hands-on. Results shown on the diagram on Figure 4 clearly show that 84,1 % of students of second group consider remote laboratory the same or more effective then hands on. Pilot group gave about the same results (72 %), and both results are comparable to the results found in other papers.

Difference of 12% can be explained by the fact that pilot group had not passed 15 experiments of this type, and they rated very high possibility to manually connect the experiment and to cope with hands-on measurement (they were mainly computer oriented engineers). Second group on the other hand rated remote experiments too high, and it was shown that it was mainly do to the saturation with other 15 experiments (high set up time, poor user interfaces and necessity to manually compute the data and draw the graphs). Thus, most of them found remote laboratory very interesting (87,3%) and they were very curious about the whole idea (93,6%). Rest of the results are found in Tables 1, 2 ad 3. For both type of experiments most highly rated was importance of preparatory instructions (96,8) and teacher presence (87,3). On the other hand, biggest problems people had with remote experiment has been the fact that they did not read preparatory instructions careful enough.

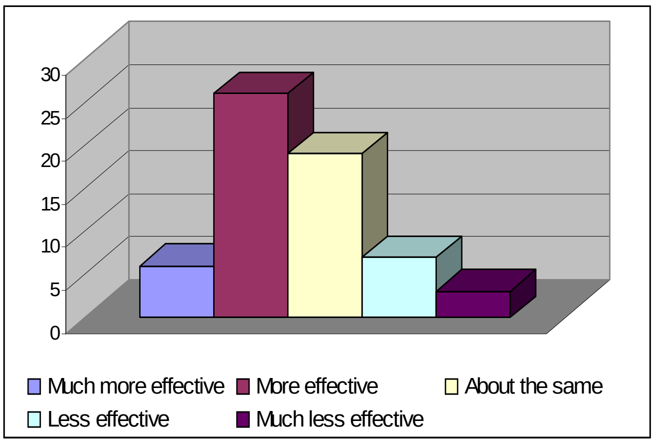

Figure 4. Effectiveness of remote laboratory comparing to hands-on

Table 1. Rating of certain aspects of remote comparing to hands-on laboratories (From scale 1 -5)

Remote vs. hands on	Mean	Std. dev.
Showing real conditions and problems:	2,9	1,08
Enabling me to apply the knowledge:	3,3	0,93
Providing wider insight in field problematic:	3,4	0,96
Providing opportunity to gain knowledge:	3,4	0,92
Providing opportunity to gain experience:	3,4	1,18
Total time required:	4,2	1,21

It was shown also that people which spent more time studying theory and preparatory instructions, had a better score. Good theoretical background and interest for the field are the most important issue of every experiment, so every remote laboratory should have entering test. Online help was not available in real time, and that was found as very important issue or even a problem hence they were facing this kind of experiment for the *first time*. There was a lot of problems with PC security issues (Java applet) and a most of people spend to much time getting familiar with the whole system (e-learning platform). This problems would all be gone if they where about to execute more experiments this way. Also, feeling of immersion was not rated as high as we expected (av. grade 3,3 with 76% of people considering it being more-less acceptable). That was mainly due to the lack of camera in the lab, or video of experiment setup procedure (video is unacceptable for dial-up connections). As expected, highly rated were conveniences in access, scheduling time and reliability of setup of remote experiment.

Table 2. Importance of certain aspects of remote and hands-on laboratories (From scale 1 -5)

Laboratory aspects	Mean	Std. dev.
Preparatory instructions	4,2	0,9
Generating lab report:	3,2	1,1
Team work:	3,8	1,2
Physical presence in lab:	3,6	1,2
Connecting the hardware:	3,8	1,1
Possibility of unexpected errors:	3,3	1,0
Convenience of scheduling:	4,1	1,0
Convenience in access:	4,2	1,0
Teacher presence:	3,8	1,2
Work with real instruments:	3,9	1,0

Table 3. Rating of certain aspects of remote comparing to hands-on laboratories

Laboratory comparision	Remote	Std. dev.	Hands-on	Std. dev.
Reliability of setup:	3,8	1,0	3,5	1,0
Trial and error in real environment:	2,9	1,1	3,3	0,9
User friendly setup procedure:	3,3	1,2	3,4	0,9
Feeling of immersion:	3,8	0,9	4,0	1,1

3. CONCLUSION

Results of testing showed that more than 72% of the tested students were considering remote experiment same or more effective than hands-on. Some correlation was shown saying that highly interested students are more interested in hands-on experiment because of showing real conditions and problems more effectively. 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, when this knowledge is strictly defined and well presented through experiment's interface. First, smaller group executed hands-on and remote experiment helping us with development of optimized model for testing advantages and disadvantages of the remote and hands-on laboratories. Second group enabled us to address critical issues of remote laboratories and to examine bigger number of students. Survey helped us understand what the critical issues of remote laboratories are and what we can do to make it better.

4. REFERENCES

[1] A. Bacciagalupi, M. Savastano, Computer-aided electrical measurements experiments, Proc. Of 5th IMEKO International symposium on "Intelligent Measurements", Jena, Germany, vol. 2 , 1986, pp 218-220.

[2] M. Bertocco, F. Feraris, C. Offelli, M. Parvis, Training of programmable instrumentation: a student laboratory, Proc. of 14th IMEKO World Congress, Tampere, Finland, vol. 2, 1997, pp.13-17

[3] J.M. Thiriet, M. Robert, M.J. Martins, M. Hoffmann, Pedagogical resources reachable via Internet for teaching intelligent instruments: developments within a European thematic network, Proc. of IEEE IMTC 2002, Anchorage, AK, USA, 2002, pp. 1475-1479.

[4] P.Arapia, A. Baccigalupi, F. Cennamo, P. Daponte, A remote measurement laboratory for educational experiments, Measurement Vol. 21, No.4, pp. 157-169, 1997

[5] N. Ranaldo, S. Rapuano, M. Riccio, E. Zimeo, A platform for distance learning including laboratory experiments, AICA 2004 Symposium, 2004, 503-516.

[6] M. Jurčević, R. Malarić, A.Sala : ''Web based platform for distance training on electrical measurements course'', MEASUREMENT 2005, Conference proceedings of 5th international conference, Smolenice, Slovakia, 2005, pp. 109-112.

[7] D. Cmuk, M. Borsic, S. Rapuano,: A Novel Approach to Multilanguage Remote Teaching: Magnetic Measurement Experiment, IMTC 2006 – Instrumentation and Measurement Technology Conference, Sorrento, Italy 24-27 April 2006, paper no. 6492

[8] Aviation Industry CBT Committee Guidelines and Recommendations, www.aicc.org.

[9] Instructional Management Systems Global Learning Consortium, IMS content packaging specification 1.1.4, 2004. www.imsglobal.org.

[10] Advanced Distributed Learning, Sharable content object reference model, 2nd edition, 2004. www.adlnet.org

[11] Corter, J. E., Nickerson, J. V., Esche, S. K. & Chassapis, C. ''Remote vs. hands-on labs: a comparative study''. Proceedings of the 34th ASEE/IEEE Frontiers in Education Conference, Savannah, Georgia, USA, October 20 - 23, 2004, pp. 17-21.