Online Teaching and Laboratory Course on Measurement Methods

http://dx.doi.org/10.3991/ijoe.v12i03.5233

Y. Kuchirka[1], M. Petriv[1], S.Baran[1], D. Ursutiu[2], C. Samoila[2],
[1]Ivano-Frankivsk National Technical University of Oil and Gas, Ivano-Frankivsk, Ukraine[1]
[2]Transylvania University of Brasov, Brasov, Romania[2]

***Abstract*—The essential demand in modern engineering education, including the measurement field, is the practical application of obtained theoretical knowledge. The advantage of a traditional university education is providing students with relevant laboratory equipment for acquiring practical skills. But these labs can be expensive and the equipment is accessible only in lab rooms. For the same reason, e-learning in the field of measurement can be effective, using online labs for obtaining such practical experience. This article describes both an online course and a hands-on lab for the study of measurement methods. The lab is suitable for modern mobile devices and does not require additional client software unlike the labs based on LabVIEW. Moreover it is based on a system that consolidates all modules for e-learning into one portable configuration.**

***Index Terms*—e-learning, measurement, online course, hands-on lab, metrology, uncertainty.**

I. INTRODUCTION

Measurement is an integral part of the industry and daily life. Definitely, there are many measurements in robotics, medicine, oil and gas, chemical, aircraft, spacecraft and other industries. For instance, measurements of technological parameters such as temperature, level, pressure, humidity, gas and fluid flow are widely used by companies in the petroleum or chemical spheres. In all areas optimal methods should be chosen depending on the required conditions of measurement, cost and accuracy. So any measured result is valuable if its accuracy can be assessed.

This is the subject of the Fundamentals of Measurement and Metrology course. The course is a basic one in Mechatronics, Automation, Robotics, Electrical Engineering, Industrial and Medical Diagnostics. This course can be taken at a college or university as well as an e-learning course. However, taking into account the advantages of e-learning compared with traditional education, namely the lower costs, better convenience and flexibility, more marketable knowledge and skills, better job focus, and more effective time applying the skills, the development of an online course on Fundamentals of Measurement and Metrology is the right solution. Nevertheless, such a course should include the main benefits of traditional education, such as full access to expensive laboratory equipment for acquiring practical skills in accordance with the requirements of the modern labor market, powerful communication and feedback environments between students and teachers, and the advantages of e-learning [1-4].

Such an online course can be developed based on the Moodle platform. Additional plugins of the Moodle platform, e.g. the Advanced Forum created by Chris Follin [5], can provide good possibilities for communication between the teachers and students. At the same time, modern web conferencing systems, e.g., open source BigBlueButton technology [6], allow improved e-learning, namely in the communication and feedback environment, based on online real-time video lectures, presentations, and teacher - student connection.

II. PROBLEM FORMULATION

The development of hands-on labs to provide students with sufficient practical skills in measurement methods is difficult. Obviously, measurement methods can be demonstrated in virtual labs. Students can also obtain artificially generated or previously measured data samples for further study. However, students prefer actual data measuring with real instruments.

Educational and commercial companies have developed a variety of laboratory trainers to study sensors, but their principles of work and application can only be used in laboratory rooms [7-8]. This leads to inefficient application of expensive equipment and the impossibility of sharing between different organizations. A serious obstacle for hands-on labs via the remote mode is the reason many people are not familiar with such technology. A lot of students and engineers know about physical labs inside their rooms, but they are intimidated by remote lab technology. They are afraid of controlling expensive equipment abroad, for example, in Spain, Romania, Germany or the U.S. Therefore, it is necessary to design hands-on labs that allow taking remote measurements and controlling these labs in an interactive mode with real-time video broadcasts, including having control over wrong user`s actions. In this case, any user will be sure the lab is working properly to avoid damage. Most current LabVIEW-based labs require installing additional software for their operation, but due to the mobility of engineers and students, online labs should be accessible on modern mobile devices by means of the usual web - browser without any additional client software [9].

Therefore, online course and hands-on laboratories for the study of measurement methods with universal web-interface should be developed that will provide not only the possibility of remote measurement and control of technological parameters but also lab control to enhance its capabilities in the future.

III. PROBLEM SOLUTION

To satisfy these requirements both an online course and a hands-on laboratory for the study of measurement methods were developed within the framework of the Tempus project "iCo-op: Industrial Cooperation and Creative Engineering Education based on Remote Engineering and Virtual Instrumentation" [10].

The objective of the course is to learn how to choose optimal measurement methods and sensors and to measure, analyze and statistically process measurement results of key technological parameters of gas and fluid. Knowledge of the Fundamentals of Mathematics and Physics is the requirement for this course. The course consists of lectures, remote laboratory work, practical work and examinations after every topic. The volume of the course is 20 study hours, and its duration is 2 months. It covers the following topics:

- Introduction to the measurement of physical quantities.
- Contact and contactless methods and instruments for liquid level measurement.
- Methods and instruments for gas flow measurement.
- Contact and contactless methods and instruments for temperature measurement.
- Methods and instruments for pressure measurement.
- Sensor calibration.
- Statistical analysis of measurement results and calculation of their uncertainty.

The structure of the online course and hands-on lab for the study of measurement methods is shown in Fig. 1.

Through the laptop or tablet (1), connected to the Internet (2), users have access to the online course in Moodle (4). Moodle provides management of online courses, theoretical materials, communication between teachers and students, examinations, etc. A learning platform Moodle (4) is installed on the web-server Apache, which is on a CentOS virtual machine in the Virtual Box environment. The web-server (3) provides the operation of Moodle, the universal graphical web interface, for the hands-on and other labs as well as a web portal. The web portal supplies the user with all information about available online courses and labs, news, video guides for help, access to the labs and Moodle, and user feedback as well as a lab booking system. The latest includes the users' database with their credentials, a lab access calendar, and the labs' access control system. It enables any registered user to choose both convenient available data and times for working in the lab. Other users do not have access to the lab at the same time if web portal administrator does not allow it. Due to the implementation of the web-portal, the Moodle, the users' database, and the lab booking system at a web-server (3) as a single virtual machine, it can be easily moved to another company. The web-server (3) receives measured data and sends control signals to the laboratory PC (6) via the Internet (7). LabVIEW-based software, installed on a PC (6), receives and processes the measured data and controls the lab activity. There is also a LabVIEW-based control service that turns on/off all labs on the PC and controls the video broadcast software. As a result, a real time video stream is acquired and compressed from the web-camera (5).

The core of the lab are two TM4C LaunchPad Evaluation Boards (TM4C) (14), based on 32-bit 80 MHz ARM® Cortex-M4F microprocessors. The TM4Cs create a block for acquiring and processing data as well as control of peripheral devices (8). Every TM4C allows acquiring up to 12 analog signals with 12-bit resolution, provides enough capacity for the lab, and leaves the possibility for its future enhancement. The two TM4C receive data from blocks of air and fluid parameters, (11) and (16), respectively (see Fig. 1). Simultaneously measured data are sent to LCD displays (12) for visual watching. The block (11) consists of 3 digital sensors: a barometer, a humidity meter, and a thermistor. The first two modules also have additional digital temperature sensors. Additionally, the barometer allows calculating the altitude of the location. The block (16) consists of the sensors and peripheral devices (20) and allows it to measure and set fluid parameters. It contains the developed hydrostatic fluid level meter (17) based on an analog pressure sensor and a hydrostatic vessel, a contactless ultrasonic fluid level meter, a thermistor and a thermocouple, which have created sub block (18). The peripheral devices (20) are controlled via a 220V switching block (13); they turn on/off a fluid heater, fluid download and upload pumps, an air compressor, a light lamp, etc. The pumps allow transferring fluid from a container (19) to a reservoir (10) through the developed hydroelectric generator (15) and the reverse. A measured output signal from the generator and the calculated fluid flow help to study the effectiveness of the generator vs. fluid flow, fluid pressure on paddles, etc. as well as the generator construction. The air compressor is used for fluid disturbance formation. The hands-on lab is shown in Fig. 2.

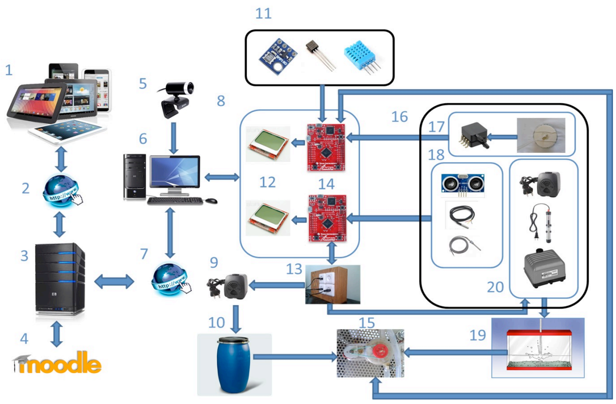

Figure 1. The structure of the online course and hands-on lab for the study of measurement methods

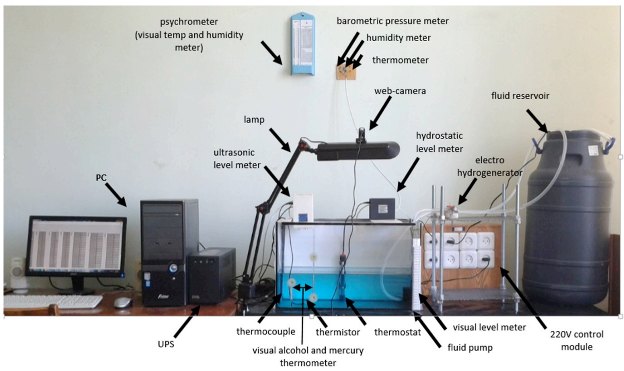

Figure 2. The equipment of the hands-on laboratory for the study of measurement methods

The configuration allows using a single web-server with a universal dynamic web-interface for interaction with different lab PCs via the Internet. The labs can be located in different departments or different countries. The labs can be based on LabVIEW or other software that provides appropriate data format. It allows design of online labs based on embedded systems (e.g. Raspberry Pi, EK-TM4C1294XL) without separate lab PCs.

In general, the lab consists of

- 3 visual fluid and air temperature sensors (mercury and alcohol thermometers);
- 3 air temperature sensors (thermistors);
- 2 fluid temperature sensors (thermistor and thermocouple);
- 1 digital and 1 visual air humidity meter;
- 1 digital barometer;
- 1 contactless ultrasonic fluid level meter;
- 1 contact hydrostatic fluid level meter, based on the analog pressure sensor;
- 1 electro hydroelectric generator; and
- 4 peripheral devices, powered from 220V.

The visual sensors are used for periodic control of the electrical digital and analog sensor operation. Users measure and control the lab via the developed graphical web-interface with video broadcast as shown in Fig. 3. They can simultaneously measure 12 parameters and control 8 peripheral devices. The web-interface is based on dynamic architecture, so the quantity of channels can be easily enhanced by adding new sensors or control devices. The advantages of the web-interface have been described in papers [9]. The lab constantly interacts with the physical hardware; therefore, it is important to ensure the safety of the lab equipment in case of incorrect user actions. Thus, the lab has additional codes that protect the hardware from damage.

The lab has a significant metrological module. It records the time and values of all the measured data in standard "txt" format. All "txt" files are compressed into a separate zip archive for optimal transfer of big volume data to users. It allows students to study and process the measured data in popular mathematical packages such as Matlab, Mathematica, and Maple. Furthermore, the lab provides users with metrological assessment of measured data, including discarding of rough misses, verification of the distribution law of measured data, and calculating A, B and extended uncertainty and so on. It should be noted that any user can choose certain or all measured signals. In this case, the web-server sends the user only the chosen data that allow optimizing the data stream. Simultaneously, the user can set technological parameters of fluid (temperature, level, flow, level disturbance). The user can use the lab during specified times (now set as an hour) and afterward the lab automatically turns off. The current version of the lab does not allow users to change the lab logics or reprogram it. This can be done in future versions of the lab to develop and verify various automatic control systems for technological parameters of fluid and gas.

The online course and web-interface of the hands-on lab support different screen resolutions and can run on different mobile devices such as laptops, tablet PCs or notebooks through the web-browser without additional client software, as shown in Fig. 4.

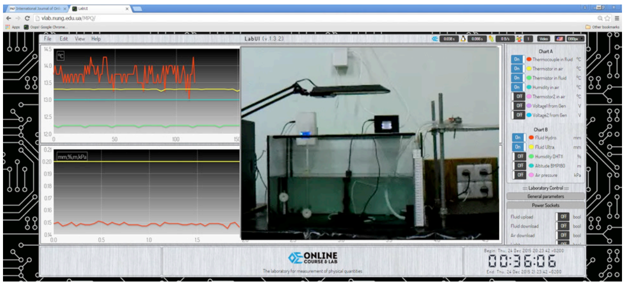

Figure 3. Web - interface of the hands-on laboratory with real-time video broadcast

Figure 4. Web - interface of the online course and hands-on laboratory

To summarize, the hands-on lab for the study of measurement methods allows performing the following remote lab work:

- to study fluid level measurement using both contact hydrostatic and contactless ultrasonic methods, including research on fluid artificial disturbance's influence on the measured level;
- to study fluid temperature measurement using a thermistor and thermocouple;
- to control the fluid level, flow and temperature while simultaneously observing their values;
- to study measurement of barometric pressure, air humidity and temperature by means of different digital thermistors;
- to research output signals from a hydroelectric generator vs. fluid flow;
- to perform digital processing of real measured data in any mathematical package, e.g. statistical and correlation analysis, approximation;
- to assess accuracy of measurement for any measured data, including calculating types A and B uncertainty as well as the extended uncertainty.

The lab provides the teacher with a good learning tool for practical application of the skills as well as for evaluation of the level users have acquired the theory of measurement methods of the technological parameters of fluid and gas and assessment of the measured results uncertainty.


ICo-op
IFNTUOG
CERTIFICATE
Mr. Oleksandr Leshko
personal identification number: MPQ/15/0012
It is hereby certified that he/she attended the training program
Measurement of Physical Quantities
held from 10.04.2015 to 10.06.2015 in Ivano-Frankivsk, Ukraine
The attendee has successfully passed the examination
The programme of the course consisted of lectures, laboratory and practical exercises and covered the following main topics:

- Introduction to the measurement of physical quantities
- Contact and contactless methods and instruments for measuring of liquid level
- Methods and instruments for measuring of gas flow
- Contact and contactless methods and instruments for measuring of temperature
- Methods and instruments for measuring of pressure
- Sensors calibration
- Statistical analysis of measurement results
- Calculation of uncertainty for measurement results

Karsten Henke
The project coordinator
Tempus
Fedir Kozak
First vice-rector of IFNTUOG
This project is funded by the European Union

Figure 5. International certificate about completion of the course for the study of measurement methods

IV. CONCLUSIONS

This year 28 employees from industrial companies took part in pilot training courses in measurement methods via e-learning, and 19 participants successfully passed the course. All users enjoyed the possibility of conducting experiments by means of notebooks with Windows and Android-based tablets at home or at work without any additional software. The students who successfully passed all of the examinations received international certificates, shown in Fig. 5.

The certificate confirms the user`s theoretical knowledge and practical skills necessary for measuring, calibrating, and statistically processing physical quantities such as level, flow, temperature, pressure.

Considering the users' feedback, we can draw the conclusion that application of the online lab allows better understanding of the theoretical material of the online course as well as obtaining practical skills in the field of measurement and control of technological parameters of fluid and gas, including uncertainty assessment of the measured results.

We hope the online course and hands-on lab meet modern requirements for e-learning. Both the online course and hands-on lab for studying measurement methods comprise the system, which consolidates the modules for e-learning, including a universal web-interface for online labs, the Moodle, the booking system, and the web-portal into one portable system. We believe the system can become a good platform for designing new and powerful online courses and labs in the future.

ACKNOWLEDGMENT

The authors would like to thank National Instruments and the Center for Valorization and Transfer of Competence (CVTC) for their support.

REFERENCES

[1] Alves G. and Garcia-Zubia J. eds. Using remote labs in education, U. Deusto, 464 pp, 2012.

[2] Rapuano F. Zoino A Learning Management System Including Laboratory Experiments on Measurement Instrumentation, IEEE Trans. Instrumentation and Measurement, vol. 55, no. 5, pp. 1757-1766, Oct. 2006.

[3] Samoila C., Ursutiu D., Cotfas P. "Enhancing Engineering Education Through Remote Experiment" Symposium on Remote Engineering and Virtual Instrumentation REV2006, Maribor - Slovenia, 29-30 June, pp 63-70, ISBN 3-89958-194-6, Kassel Press-Editor M.Auer-2006.

[4] Auer M., Pester A., Ursutiu D., Samoila C. Distributed Virtual and Remote Labs in Engineering. In: Proceedings of the IEEE International Conference on Industrial Technology (ICIT), vol. 2, pp. 1208-1213. Maribor, Slovenia, 2003.

[5] Advanced Forum. [Online]. Available: https://moodle.org/plugins/view/mod_hsuforum.

[6] BigBlueButton. [Online]. Available: http://bigbluebutton.org/

[7] QNET Mechatronic Sensors Trainer. [Online]. Available: http://www.quanser.com/products/qnet_mechatronic.

[8] Transducers and Instrumentation Trainer. [Online]. Available: http://www.edibon.com.

[9] Y. Kuchirka, L.Vytvytska, D. Ursutiu, C. Samoila - "An Online Course and Laboratory for Studying Automatic Control Systems", International Journal of Online Engineering, vol. 12, № 1, 2016.

[10] ICo-op. [Online]. Available: www.ico-op.eu.

AUTHORS

Y. Kuchirka and **S.Baran**, the Department of Information and Measuring Technologies of Ivano-Frankivsk National Technical University of Oil and Gas, Ukraine (e-mail: kuchirka.wsinrs@gmail.com).

M. Petriv, the Department of Methods and Devices of Quality Control and Product Certification of Ivano-Frankivsk National Technical University of Oil and Gas, Ukraine (e-mail: hifi.ua@gmail.com).

D. Ursutiu and **C. Samoila**, the Creativity Laboratory of CVTC-Transylvania "University" of Brasov, Romania (e-mail: udoru@unitbv.ro and csam@unitbv.ro).

The project "ICo-op – Industrial Cooperation and Creative Engineering Education based on Remote Engineering and Virtual Instrumentation" was supported by the European Commission within the "Tempus" program, Grant No 530278-TEMPUS-1-2012-1-DE-TEMPUS-JPHES. Submitted 09 November 2015. Published as resubmitted by the authors 15 January 2016.