COOPERATIVE WEBLAB:
A Tool for Cooperative Learning in Chemical Engineering in a Global Environment

G.A.C. Le Roux,[1] G.B. Reis,[2] C.D.F. de Jesus,[2] R.C. Giordano,[2] A.J.G. Cruz,[2]
P.F. Moreira, Jr.,[1] C.A.O. Nascimento,[1] and L.V. Loureiro[1]
[1] *Polytechnic School, University of São Paulo • 05508-900, São Paulo, SP, Brazil*
[2] *Federal University of São Carlos • São Carlos, SP, Brazil*

This paper describes the use of Weblabs—Web-based experiments—for cooperative learning by students working together from two different locations to conduct experiments and write reports.

In 2004, the São Paulo State's Agency for Research Development (FAPESP) established a program to study and develop the usage of technology and applications in advanced Internet for research and educational purposes (KyaTera). The platform is an optical high-speed packet network interconnecting a number of laboratories, research institutes, and universities in the state of São Paulo, Brazil. One of the projects of KyaTera is the Cluster of Weblabs for Chemical and Biochemical Process Engineering, which form a collaborative research between University of São Paulo (USP); the Federal University of São Carlos (UFSCar); and University of Campinas (UNICAMP). This project aims to develop a set of real experiments, available through the Internet, for chemical engineering students at the undergraduate level. Other KyaTera projects and the annual report can be found at <www.kyatera.fapesp.br>.[1]

REVIEW AND PREVIOUS WORKS

The application of Weblab experiments in chemical engineering education was first reported in 1998.[2] After this paper, the same author published a series of articles on the subject in the *Proceedings of the American Society for Engineering Education* and in subsequent papers.[3-9] These articles show the evolution of Weblabs' usage for academic purposes either locally or internationally.

Unit operations and process control Weblabs for chemical engineering education purposes were also developed.[10, 11] Only more recently were collaborative Web-based experiments in local environments implemented and presented.[12, 13]

***G.A.C. Le Roux** is an associate professor of chemical engineering at The University of São Paulo. He has research interests in mathematical modeling, simulation, and process synthesis and control, with emphasis on parameter estimation methods and system identification.*

***G.B. Reis** is a Ph.D. candidate in the Department of Electrical Engineering at The University of São Paulo in São Carlos. He has a M.Sc. in chemical engineering from The Federal University of São Carlos.*

***C.D.F. de Jesus** is a process engineer at the Bioethanol Science and Technology Center. Dr. de Jesus received his Ph.D. in chemical engineering from The Federal University of São Carlos. His main activities are process modeling, software development, data acquisition of biotechnological experiments, and biodiesel plants commissioning.*

***R.C. Giordano** is a full professor of chemical engineering, and is head of the Chemical Engineering Department and of the Laboratory for Development and Automation of Bioprocesses (,www.ladabio.deq.ufscar.br.) at The Federal University of São Carlos.*

***A.J.G. Cruz** is an associate professor of chemical engineering at the Federal University of São Carlos. His research focuses on biotechnological applications of computer-aided process engineering.*

***P.F. Moreira, Jr.,** is a research fellow at The University of São Paulo. His roles include software and hardware development and system integration specialist.*

***C.A.O. Nascimento** is a full professor of chemical engineering, and head of the Center for Environmental Research and Training at The University of São Paulo. Dr. Nascimento is also a member of the Environmental Committee of the Industrial Federation of State of São Paulo.*

***L.V. Loureiro** is a professor of chemical engineering at The University of São Paulo. Dr. Loureiro is also executive director of the Fulbright Commission in Brazil and has an extensive background in international educational and graduate academic exchanges.*

Two international workshops—iLabs Workshop @ MIT, Jan. 24–27, 2005, in Massachusetts, and Weblabs in Chemical Engineering, July 8, 2005, in Cambridge, England—were organized by the Massachusetts Institute of Technology and University of Cambridge, respectively, with representatives from many institutions from various countries, *e.g.* Technologico de Monterrey, Mexico; ENSIACET, France; University of Leipzig, Germany; and University of São Paulo, Brazil. The purpose of the workshops was to discuss Weblabs as an educational tool, along with the potential developments and outcomes.

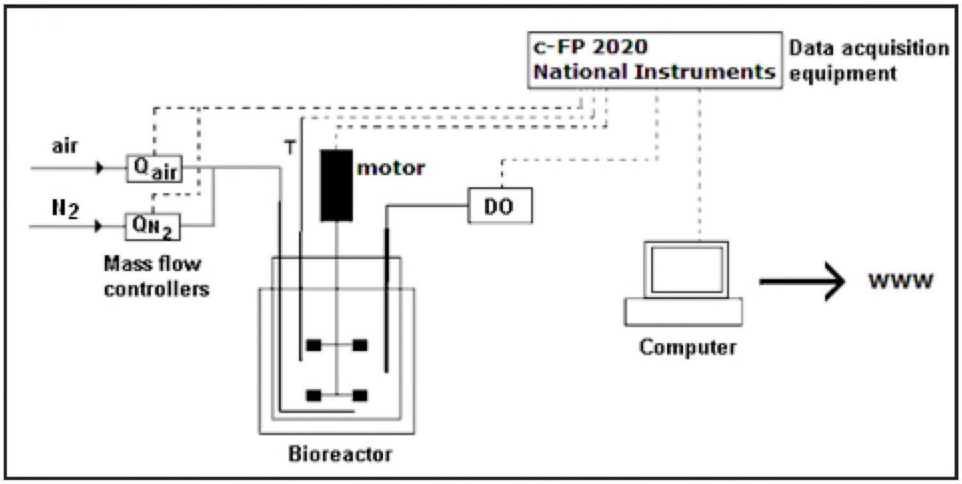

Figure 1. *Diagram of mass transfer experimental setup.*

A comprehensive set of Weblabs for chemical engineering student training has been developed at University Leipzig by Ralf Moros, under supervision of Prof. Helmut Rapp. Their work in the field was recently presented at the 2nd International Workshop on e-learning and Virtual and Remote Laboratories, in February 2008, at Potsdam, Germany, at an event organized by The University of Potsdam.

WEBLAB AND COOPERATIVE WEBLAB IN CHEMICAL ENGINEERING

The term Weblab was first employed to describe real experiments—in contrast to virtual ones—remotely operated via the Internet. This type of experiment has been proposed and implemented worldwide by some major universities. In this article it is introduced a unique approach for Weblabs: Cooperative Weblab (CW). This new format for Weblabs promotes intercultural experiences to students while also allowing them to develop communication skills. CW experiments must be performed by two groups of undergraduate students, in two different locations.

The collaboration among the students is achieved by gathering participants of two different Weblabs into working groups that are asked to simultaneously solve a technical problem, for which an experiment setup is available. This procedure emulates challenges that will frequently take place in their future professional lives. The CW also fosters the learning of essential chemical engineering concepts. Students from different Weblabs must work cooperatively to achieve these goals.

CASE STUDY: CW BETWEEN USP AND UFSCAR

The CW concept was tested with two Weblabs of chemical engineering departments, one at USP and the other at UFSCar, both supported by KyaTera. These Weblabs are 250 km apart and they are at two of the top five chemical engineering programs in Brazil.

Mass Transfer Weblab at UFSCar

During the aerobic cultivation of microorganisms or cells in tank bioreactors, the level of dissolved oxygen must be kept high enough for the organisms to thrive. Thus, it is important for the education of chemical engineers to learn the fundamentals of mass transfer herein involved, and to get familiar with techniques that assess rates of oxygen transfer from the gas phase into the liquid culture medium as well. A scheme of the Weblab for mass transfer experiments is presented in Figure 1.

The dissolved oxygen is removed from the liquid phase by bubbling nitrogen into the medium. After reaching zero oxygen concentration, the nitrogen flow stops and air flow starts. An electrode probe measures the dissolved oxygen (DO) in the liquid phase. The mass transfer coefficient is represented by the parameter k_La that is estimated by fitting a model for the change of the DO to the experimental data. The experiment aims to calculate k_La values at different operating conditions of air flow rate and stirrer speed employing the gassing-out method.[14, 15]

The bioreactor is an aerated and stirred tank reactor. Gas (air and nitrogen) under pressure is supplied to the sparger (a ring with holes) located inside the reactor and above of the impeller. The system consists of a stirrer with two Rushton impellers. This impeller is typically a disc with 6 to 8 blades designed to pump fluid into a radial direction. The Weblab was built employing National Instruments hardware for data acquisition and LabVIEW software as the supervisory system.

Figure 2 shows the main screen of the Weblab for mass transfer experiments. The users can choose the experiment operating conditions (air flow rate and stirrer speed) through this screen.

Reactor Temperature Control Weblab at USP

The Continuous Stirred Tank Reactor (CSTR) is one of the most simple and, at the same time, powerful devices in the chemical industry. It involves many important aspects of chemical engineering process (*e.g.*, heat transfer, mass transfer, chemical reactions) leading, in this experiment, to the development of process control strategies (<http://weblab.pqi.ep.usp.br>).

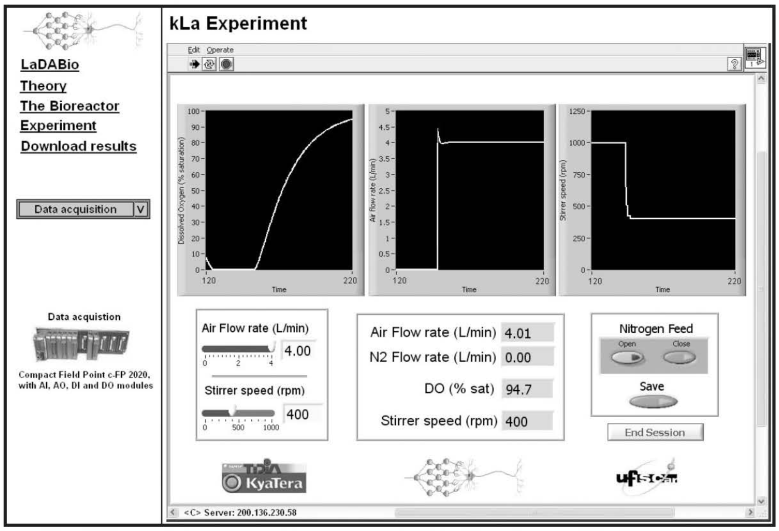

Figure 2. *Mass Transfer Weblab interface.*

The reactor is a jacketed glass vessel with 4.5 L capacity. At the inner part of the reactor there is a stainless steel coil connected to a 3,000 W thermal bath, a hot water source, a temperature sensor, and a double helix impeller. The jacket is connected to a cold water source, at room temperature. The hot and cold water flows can be controlled by electro pneumatic valves. An electrical heater is plunged inside the reactor, to simulate different reactions' thermodynamic behaviors. A digital power module controls the electrical tension supplied to the resistor.

The reactor temperature can be controlled by varying the hot water flow to the coil or the cold water flow to the jacket. Figure 3 shows a screenshot of the temperature control interface. This screen also includes a Webcam to remind the users that they are dealing with an actual setup and not with a simulator.

PERFORMING THE CW EXPERIMENTS

To perform the CW experiments, two students at UFSCar and two at USP form a group. An instructor supervises the students at each Weblab. The group is invited to define the experimental procedure and the tasks of each member during the experiment. Students communicate using videoconference software that gives participants an improved sense of reality.

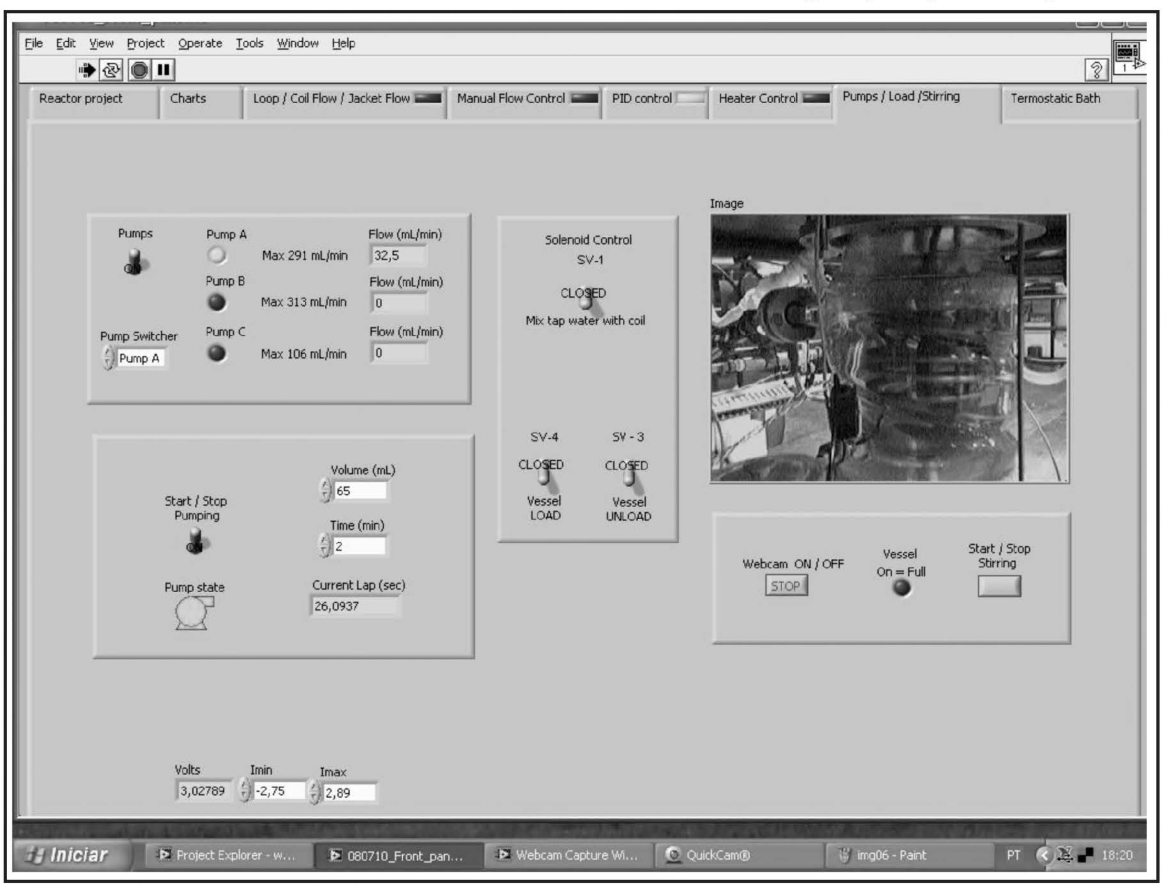

Figure 3. *Reactor Temperature-Control Weblab interface.*

During the experiments students exchange information and opinions about the phenomena that take place. In the mass transfer experiment, the main concerns are about the quality of the mixing, the size of the bubbles, and the various problems that arise during the experiment (*e.g.*, bubbles blocking the tip of the probe, high coalescence phenomena, and conditions of inefficient mixing). In the reactor temperature control experiment, a step change on the coil flow is performed to obtain the response curve. The students must perform calculations together during the experiment to apply the Cohen-Coon procedure to obtain the PID tuning parameters.[16] The set of PID tuning parameters is implemented by closing the control loop and is tested by different methods (*e.g.*, set point changes and disturbance rejection tests). Students are invited to test other disturbances with the immersed resistor in the reactor.

A high level of interactivity takes place among the students during the experiment. At the end of experiment, the students must process the data and prepare the final group report. The students are also invited to use the network to communicate and prepare the report.

CONCLUSIONS

The CW experiments are a privileged learning environment and are complementary to the experiments run in regular labs. There are at least two positive aspects of the CW experiments worth pointing out. The first is that the students can better develop teamwork skills through quasi-professional life experiences. In a CW experiment, they must work with formerly unknown colleagues, with different engineering education, to reach common goals. This is a big challenge, particularly for undergraduates, accustomed only to interacting with their engineering schoolmates and teachers. Furthermore, the open-ended problems methodology adopted in the CW experiments also invites the participants to have a stronger interaction, fostering the teamwork skills. The other aspect is the playfulness of remote control of real equipment and interaction with colleagues in a distant location, in an environment—the Internet—that is very familiar to the students. It also stimulates them to perform the CW activities, *e.g.*, the experimental procedures and reports, with additional interest and dedication for even well-known experiments.

The overall opinion of students was extremely positive and encourages the increase of the number of participating institutions in the CW experiments. This will allow a sound assessment of results in a shorter period of time. CW experiments are valuable educational tools in a world with an increasing interaction between diverse people in general and, particularly, between professionals in the field. Special effort is necessary to fit this kind of activity in the curricula of chemical engineering programs, because it involves two or more institutions. In the case of Weblabs in different countries, some practical hurdles must also be faced and overcome, such as the difference in time zones, calendars, and language. Nonetheless, the impact of these issues is outweighed by the potential improvement that this tool can bring to the chemical engineering education.

ACKNOWLEDGMENTS

Authors would like to thank the São Paulo State's Agency for Research Development (FAPESP) for its financial support.

REFERENCES

1. *Kyatera Program Annual Reports*, available at <www.kyatera.fapesp.br>
2. Henry, J., "Running Laboratory Experiments via the World Wide Web," ASEE Annual Meeting, Seattle, WA, June 1998. Available at <http://soa.asee.org/paper/conference/paper- view.cfm?id=14005>
3. Henry, J., "24 Hours, 7 Days Lab Experiments Access on the Web All the Time," ASEE Annual Meeting, St. Louis, MO, June 2000. Available at <http://soa.asee.org/paper/conference/paper-view.cfm?id=14757>
4. Henry, J., "Laboratory Remote Operation: Features and Opportunities," ASEE Annual Meeting, Charlotte, NC, June, 2001. Available at <http://soa.asee.org/paper/conference/paper-view.cfm?id=16109>
5. Henry, J., "Using the Modern Chemical Engineering Laboratory at a Distance," ASEEAnnual Meeting, Montreal, Quebec, Canada, 2002. Available at <http://soa.asee.org/paper/conference/paper-view.cfm?id=16833>
6. Henry, J., and C. Knight, Modern Engineering Laboratories at a Distance, *Int. J. Eng. Ed.*,19 (3), 403-408, 2003.
7. Henry, J., and H.M. Schaedel, "International Cooperation in Control Engineering Education Using Online Experiments, *European J. of Eng. Ed.*, **30**(2), 265 (2005)
8. Henry, J., and R. Zollars, "Introducing Reality Into Process Control Classes," ASEE Annual Meeting, Portland, OR, 2005. Available at <http://soa.asee.org/paper/conference/paper- view.cfm?id=22094>
9. Slater, C.S., R.P. Hesketh, D. Daniel Fichana, J. Henry, A.M. Flynn, and M. Abraham, "Expanding the Frontiers for Chemical Engineers in Green Engineering Education," *Int. J. Eng. Ed.*, **23**(2), 309 (2007)
10. Shin, D., E.S. Yoon, K.Y. Lee, and E.S. Lee, "A Web-Based, Interactive Virtual Laboratory System for Unit Operations and Process System Engineering Education: Issues, Design, and Implementation," *Computer and Chem. Eng.*, **26**, 319-330 (2002)
11. Selmer, A., M. Goodson, M. Kraft, S. Sen, V. Faye McNeill, B.S. Johnston, and C.K. Colton, "Performing Process Control Experiments Across the Atlantic," *Chem. Eng. Ed.*, **39**(3) (2005)
12. Gillet, D., A.V. Ngoc, and Y. Rekik, "Collaborative Web-Based Experimentation in Flexible Engineering Education," *IEEE Transactions on Education* **48**(4), 696 November (2005)
13. Henry, J., and R. Zollars, "Learning-By-Doing and Communications within a Process Control Class," ASEE Annual Meeting, Chicago, IL, 2006. Available at <http://soa.asee.org/paper/conference/paper-view.cfm?id=1888>
14. Shuler, M. L., and F. Kargi, Bioprocess *Engineering: Basic Concepts*, 2nd Ed., Prentice Hall International Series, Upper Saddle River, NJ, 2002.
15. Blanch, H.W., and D.S. Clark, *Biochemical Engineering*, Marcel Dekker, Inc., New York (1997)
16. Seborg, D.A., T.H. Edgar, and D.A. Mellichamp, *Process Dynamics and Control*, John Willey & Sons, New York (1989) ❐