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Cooperative WebLab in chemical engineering between France and Brazil: Validation of the methodology

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ABSTRACT

A WebLab is an experiment operated remotely via Internet. Besides the strictly technical aspects of such an experiment, which may contribute to the learning of Chemical Engineering fundamentals, there is also important feedback when teams of students of two different countries are working together: the WebLab becomes an intercultural experience, enhancing the communication skills of the students. A WebLab between Universidade Federal de São Carlos (DEQ/UFSCar) and the Ecole Nationale Supérieure d'Ingénieurs en Arts Chimiques et Technologiques (ENSIACET) is presented in this work. A mass transfer experiment in a bench scale reactor (stirred and aerated) had to be studied by mixed teams, thus emulating challenges that will be common in future working environments. In order to perform the experiment, students in Brazil and in France were put into groups. The students had to make decisions about the procedure for executing the experiments. All the students were able to control the equipment, no matter where they were physically. Students communicated using video conference software. The students' and teachers' opinions of this experience were very positive. This methodology is an important contribution to the education of engineers in a world integrated by modern communication technologies.

Keywords: Cooperative WebLab; Internet experiment; Chemical engineering; iLabs

1. Introduction

Online laboratories ("WebLabs" or "iLabs") are experimental setups that can be accessed through the Internet from a regular web browser. iLab was born in microelectronics classes taught by the electrical engineering professor Jesus del Alamo of MIT, in 1998 (iLab project homepage, 2011). From time to time, this concept is used by other disciplines like chemical engineering (Henry and Knight, 2003; Klein et al., 2005; Shin et al., 2002).

In a workshop about WebLabs in Chemical Engineering that took place in Cambridge, UK (Selmer and Kraft, 2011; Moros, 2005), three main kinds of WebLab use were found to be the most promising:

1. Very small setups of a few centiliters (Moros, 2005; Selmer et al., 2005) that do not need to be locally supervised. Their main advantage is more convenient access to the labs. Experiments can be carried out from anywhere at any time.
2. Pilot-scale setups from a few liters to tens of liters, which

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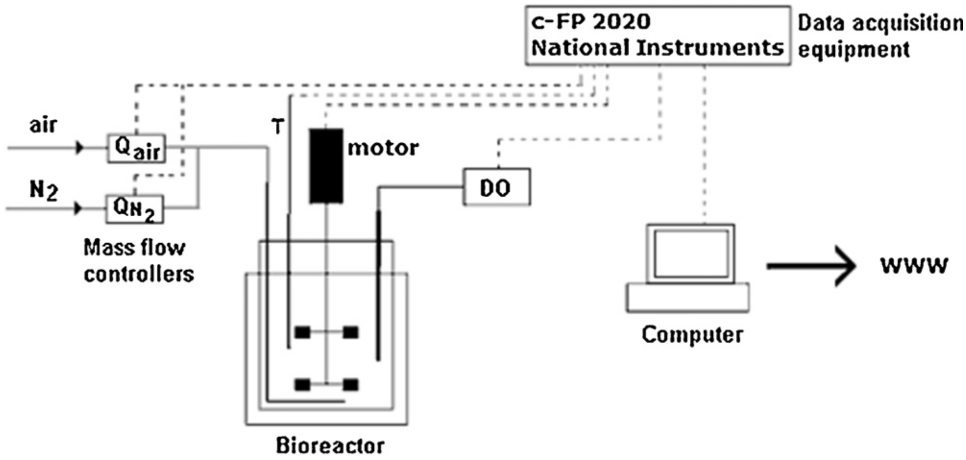

Fig. 1 – Experimental setup used for k_La determination.

are conducted by two groups of people: one group close to the equipment, the other anywhere in the world. Their main advantages are, first, to enable the plant to be operated from far away as is increasingly done in industry and, second, to promote intercultural exchanges.

3. Specific experiments that are used few times and are expensive. More people can access such equipment, thus contributing to its financial equilibrium.

An experimental setup for the determination of mass transfer coefficient was prepared for remote experiments at the Laboratory for Development and Automation of Biochemical Processes (LaDABio) of the Chemical Engineering Department of the Universidade Federal de São Carlos (DEQ/UFSCar) with the support of the Kyatera program. This program was established by the São Paulo State Agency for Research Development (FAPESP) to study and develop the use of technology and applications in advanced Internet for research and educational purposes (KyaTera). One of the projects that originated in Kyatera is the "Cluster of WebLabs for Chemical and Biochemical Process Engineering", which aims to develop a set of real experiments, available through the Internet, for chemical engineering students at undergraduate level. Other KyaTera projects and the annual report can be found at http://www.kyatera.fapesp.br.

In order to validate the methodology, a WebLab was implemented between LaDABio and the Process Engineering Department of the Ecole Nationale Supérieure d'Ingénieurs en Arts Chimiques et Technologiques (ENSIACET).

One of the main objectives of this WebLab experiment is to offer students intercultural experience while enhancing their communication skills. At the same time, a technical problem has to be solved by heterogeneous teams, thus emulating challenges that will be common in their future work environment. And, last but not least, even though the objective of this WebLab is not to replace actual experiments, it helps in the assimilation of concepts concerning Chemical Engineering fundamentals. To achieve these goals, the students of both countries are required to work in synergy.

During 4 different sessions, 14 students from ENSIACET and 8 students from DEQ/UFSCar were invited to study a system physically located at LaDaBio using remote access. The WebLab consisted of a mass transfer experiment in a bench-scale reactor (stirred and aerated). The experiment applied the gassing-out dynamic method to determine the volumetric oxygen mass transfer coefficient (k_La) for different conditions of stirring and aeration.

In order to perform the experiment, two students in Brazil and three or four in France worked as a group, supervised by teachers of each country. The students had to decide on the measurements that were to be made and on the experimental protocols (who controls what). As only the students in Brazil were able to interact physically with the system, web-cameras were installed in order to allow the students in France to follow the experiment visually. Students communicated using conventional video conference software.

Each student was invited to answer a questionnaire intended to assess his/her expectations before the experiment, and another one after the final report was returned. This work compiles the opinions of the students and teachers in order to sketch a portrait of the pedagogical impact of this type of experiment.

2. Determination of mass transfer coefficient (k_La): theory

During the aerobic growth of microorganisms or cells in tank bioreactors, the level of dissolved oxygen must be kept high enough for the organisms to thrive. It is important for future (bio-)chemical engineers to master the fundamentals of mass transfer involved, and also to become acquainted with techniques for assessing rates of oxygen transfer from the gas phase into the liquid culture medium.

The method used in the WebLab to determine k_La was the unsteady state method ("Gassing-out Method"). In this method, the dissolved oxygen is removed from the liquid phase by sparging nitrogen into the medium. When the dissolved oxygen concentration (DO) reaches a value of zero, the nitrogen feed is interrupted and the air flow is restarted. DO is monitored until the solution is nearly saturated. Assuming ideal mixing in the liquid phase, the mass balance for DO in the liquid phase during the re-aeration can be expressed by Eq. (1).

$$\frac{dC}{dt} = k_La \cdot (C^* - C) \tag{1}$$

where C^* is the DO saturation concentration and C is the DO concentration

Eq. (1) is suitable when fast probes are employed. If a fast probe is not available, the dynamics of the electrode should