A New Laboratory Course to Teach Electrophysiology in Spanish or English

Robert N. Schmidt, MS, MBA, JD, PE, Esq.
Chairman, Cleveland Medical Devices, Inc., Cleveland, Ohio 44103 USA

Abstract – Biomedical engineering and health sciences are two of the fastest growing fields for new job creation. Demographics demand new technologies and personnel to deal with an aging population. New innovative, affordable teaching tools are required to train a new generation of workers for these high-tech 21st Century jobs. An innovative laboratory course was developed to integrate wireless electrophysiology systems with a hands-on learning approach. The lab course is available in either Spanish or English.

The course contains 25 laboratory sessions in four areas: basic data principles, basic physiology, advanced physiology, and clinical applications. The labs prepare students with an appropriate skill set for real-world problems. Education of biomedical engineers and health science students requires practical learning with cutting edge technology to produce graduates who are prepared to solve problems in the clinic, in research, or in industry. Including a wide range of clinical and rehabilitation applications allows a school that includes this lab course in its curriculum to tailor the lab to their educational program and increases student interest. These laboratories were designed to encompass both the basics of physiological signals and methods for effectively utilizing them in clinical applications. These clinical application interfaces are critical for student comprehension of how physiological signals may be manipulated to extract meaningful parameters for diagnosis of various medical disorders and determination of rehabilitation needs. The laboratory course presented in this paper was implemented and evaluated at a number of universities. Utilizing a virtual environment for practical applications provides the most cost-effective way to give students hands-on experience.

Keywords – Biomedical Engineering, Health Sciences, Electrophysiology, Education, LabVIEW, Laboratory Course, Data Acquisition, Wireless

INTRODUCTION

The demand for biomedical engineers in both industry and academia reflects the large social and economic impact the field creates. The United States Department of Labor reports that the number of biomedical engineering (BME) jobs will increase by 31.4% through 2010, more than double the average predicted rate in other fields.[1] Similarly, the demand for health science (HS) students keeps growing to service an ever aging population.

BME & HS play an important role in affecting outcomes for medical disorders and rehabilitation needs. Thus, BME & HS education has a responsibility to effectively prepare students to approach and solve the health problems that come as a result of an aging society.

It is important for BME & HS students to first understand data acquisition and physiological fundamentals and application of these fundamentals to clinical problems. Utilizing the most advanced wireless electrophysiology equipment in a laboratory setting improves students' experience and interest in their field. As a consequence there is an increased need for applied learning focused on the latest clinical, industrial, and research applications. Once students understand how fundamentals can be applied to satisfy wide-ranging health and rehabilitation needs, they gain a better appreciation for biomedical theory. The National Science Foundation recently reported that engineering education should include "integrative laboratory experiences that promote inquiry, relevance, and hands-on experience."[2] The Tulane BME study reported that students preferred to receive information visually (preferred by 88% of the student sample) rather than verbally, focus on sensory information (55%) instead of intuitive information, process information actively (66%) instead of reflectively, and understand information globally (59%) rather than sequentially.[3] [3]. The course was designed to incorporate all of these learning preferences.

Table 1 CleveLabs provides 24+ laboratory sessions; schools may present or omit selected sessions to fit their curriculum

Basic Data Principles	**Advanced Physiology**
Data Acquisition Basics	Speech Recognition
Digital Signal Processing	Polysomnography
Statistical Analysis	Electrocardiography II
Image Processing*	Electroencephalography II
Post-Processing Toolbox	Electromyography II
	Spirometry
	Blood Pressure
Basic Physiology	**Clinical Applications**
Biopotential Basics	Biofeedback
Electrocardiography	Gait Pattern Recognition
Electroencephalography	Environmental Controls
Electromyography	Heart Rate Detection
Electrooculography	Alertness Detection
Respiration	Motor Control

Table 1 shows the sessions for the BME & HS laboratory course platform that successfully integrated basic data principles, basic physiology, advanced physiology, and real world clinical applications to better train and challenge BME & HS students. This innovative laboratory course has been implemented into the curriculum at a score of universities.

II. METHODS

A. CleveLabs Course Hardware

The BioRadio® 150 (**Figure 1**) is a lightweight, wireless physiological monitor with 12 channels. In addition to eight programmable electrophysiology channels, the device also has a digital input (usually used for a pulse oximeter), a DC input (frequently used for inputs such as a oral/nasal temperature thermistor, CO_2 sensor, respiratory effort belt, spirometer, blood pressure cuff, or other low-frequency sensor), an air pressure sensor, and a built-in accelerometer to determine body orientation.

Figure 1 The BioRadio 150

The BioRadio 150 hardware was developed as the hardware platform for integration into the laboratory course system to meet the needs of, and to maximize flexibility for, different schools and their education focuses. Its small size saves laboratory space and allows any room with a computer to become a BME or HS laboratory. Additionally, its wireless design removes cumbersome tethered leads and increases the flexibility of potential locations and applications, allowing for studies to take place anywhere, from the sports field to the KC-135 “Vomit Comet” for zero-gravity testing. With a laptop computer, the battery operation allows the lab to be performed even where there is no electric power.

The subject-worn unit includes eight channels of programmable physiological inputs. Each channel can be programmed for a particular input range, sampling rate, resolution, and AC or DC coupling so that many types of signals can be monitored with the same device. For example, potential input signals for each channel include (but are not limited to) electrocardiography (ECG), electroencephalography (EEG), electromyography (EMG), and electro-oculography (EOG).

Figure 2 CleveLabs Laboratory Course allows students to have hands-on experience acquiring electrophysiologic data.

The subject-worn unit amplifies, digitizes, and telemeters data to a computer located up to 70 meters from the subject (or 25 meters though two walls indoors). A computer unit connected to the student computer via a USB port receives the telemetered data. The two-way communication protocol allows data packets to be retransmitted if necessary. This hardware platform exposes students to state-of-the-art technology compared to traditional rack-mounted amplifiers and filters.

B. CleveLabs Course Software

The BioRadio 150 hardware interfaces with National Instrument’s LabVIEW™ graphical user interface software through a BioRadio LabVIEW driver. The driver utilizes a dynamically linked library to stream data from the computer serial port directly into LabVIEW, with no requirement to purchase LabVIEW. The LabVIEW programming language is a popular tool in education, research, and industry for data acquisition software and virtual lab system controls. Thus it provides a familiar environment for users to intuitively operate the course application software and also to design their own laboratories (**Figure 2**). Virtual instruments facilitate problem-solving and decision-making. Sub virtual instruments (VIs) were designed for integration into the Windows-based programming language for starting, reading data, and stopping. The sub VIs were used in the course application software as well as in example development libraries to support student-designed software. In addition to the LabVIEW libraries, separate driver libraries were also created for use in the MATLAB® programming environment.

C. CleveLabs Curriculum

Wide-ranging laboratory topics are available to introduce students to several areas of interest. These areas (basic data principles, basic physiology, advanced physiology, and clinical applications) allow each school and instructor, at each education level, to select the topics that are appropriate for them. Initial laboratory sessions introduce the basics of data acquisition and processing and the physiological mechanisms underlying the recorded signal, teach students how to acquire data from themselves, and demonstrate effective physiological signal processing.

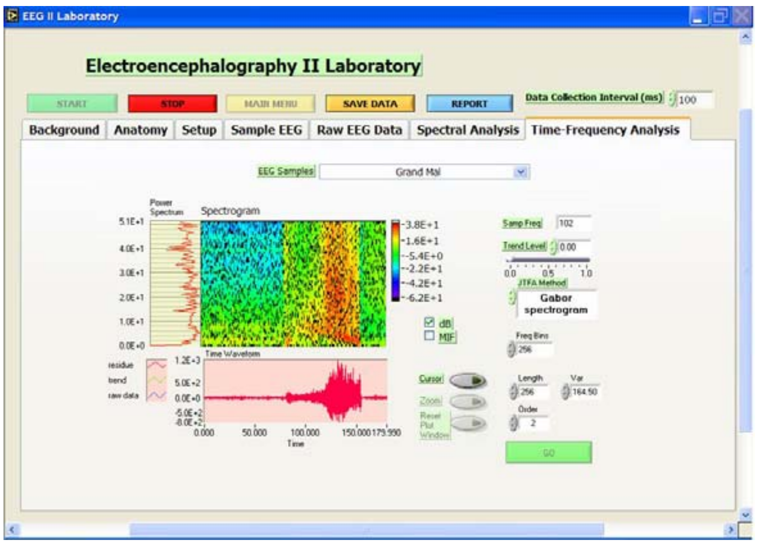

Figure 3 Abnormal databases are presented for a variety of clinical disorders including brain function (seizures) shown above. Students utilize time-frequency analysis methods to extract features.

Intermediate sessions introduce abnormal clinical signals (**Figure 3**). Later sessions apply the signals in clinical applications. Each laboratory session incorporates detailed setup instructions (**Figure 4**) and user-friendly features for saving, analyzing, and reporting results (**Figure 5**). Students process and analyze signals both in real-time and offline. The clinical labs allow students to be introduced to looking at clinical problems such as: using biofeedback as a mechanism to improve relaxation or sports performance, evaluating heart rate detection for diagnosing cardiac problems, and using gait pattern recognition to help diagnose disease. The labs also introduce the students to leading edge research such as motor control of robotics (**Figure 6**), and using human-computer interfaces to control a computer or the patient's environment.

The laboratory course minimizes overhead time associated with hardware setup, equipment troubleshooting, and data management, while maximizing the time spent critically analyzing and applying collected data. Finally, the course integrates learning styles shown effective for most BME & HS students including active, sensing, visual, and global learning [3].

D. CleveLabs Course Integration

The CleveLabs system has been implemented at many universities, including the University of Southern California, the University of Toronto, Case Western Reserve University, Bucknell University, Stevens Institute of Technology, and Lake Forest College (LFC). Laboratory course materials include:

1. **Wireless BioRadio** physiological signal acquisition system;
2. **Software** including:
   a. ***CleveLabs Laboratory Course Software***: This software installs the CleveLabs software and the BioRadio Capture Lite software. It includes the PDF Teacher Edition Lab Chapters and the PDF Student Edition Lab Chapters in a folder on the CD. (The teacher edition chapters are identical to the student

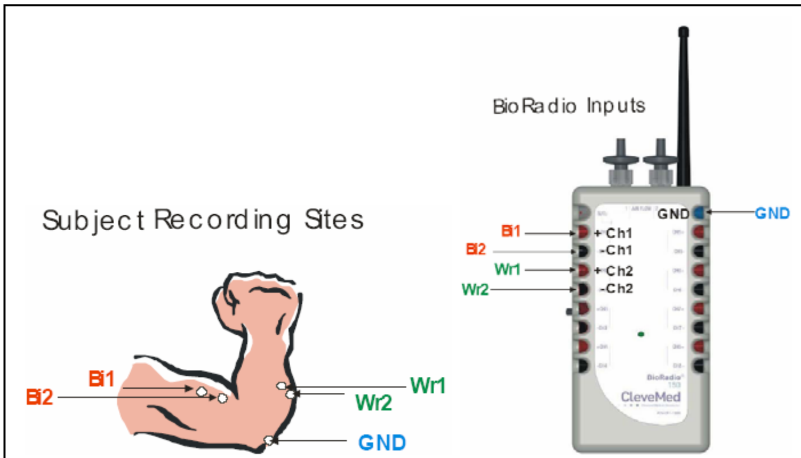

Figure 4 Step-by-step instructions make it easy for students to learn the basics

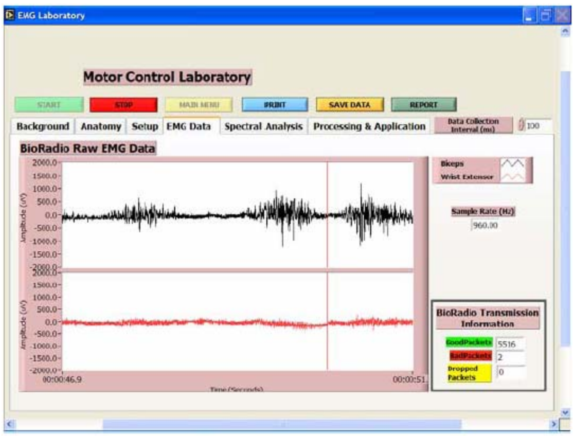

Figure 5 Student-friendly saving, analyzing, and reporting features make the course easy to step through at the student's own pace.

chapters but contain suggested answers and screenshots.)

b. ***CleveLabs Laboratory Course Software with Image Processing***. This software retains the features described above and additionally includes the Image Processing lab session.

c. ***Student Design and Analysis Toolbox***. This software installs the CleveLabs software so that students can read the PDF files, explore the software before class, and use the included Post Processing Toolbox to analyze saved data after class, but does not communicate with the BioRadio. It also includes LabVIEW driver files in a folder on the CD with documentation and examples showing how students can develop their own LabVIEW code to use the BioRadio for custom experiment setups. Finally, the Student Design and Analysis Toolbox includes MATLAB driver files with documentation and examples showing how to develop custom BioRadio MATLAB code. LabVIEW and MATLAB code examples, more extensive than the free examples available from CleveMed.com, assist students in developing custom experimental setups for their own data collection and analysis research.

3. **Accessories** include gold cup electrodes, snap electrodes, cotton swabs, skin prep, and snap leads.

Professors, teaching assistants, and students from the initial user base provided feedback after completing laboratories. User feedback assists in annual revisions of the developed laboratory course. Feedback included suggestions for improving ease of use, fixes for technical issues, curriculum advisement, and anecdotal commentary in students' subjective experiences with the laboratory course sessions.

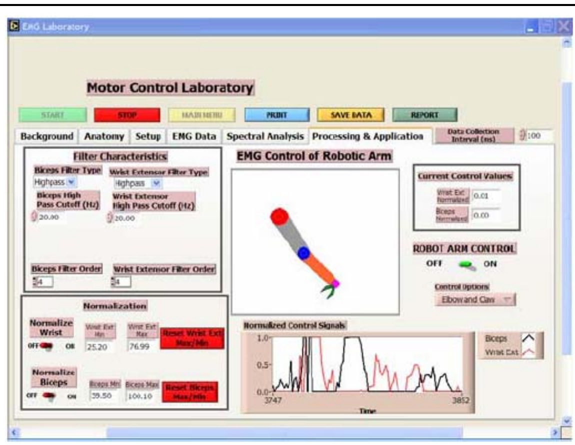

Figure 6 Labs like the Motor Control Lab let students use their own muscles control a virtual robot arm. This gives the student an exposure to leading edge research at a nominal cost.

III. RESULTS

A wide range of laboratory topics was implemented (Table 1) whereby course sessions could be approached in a sequential manner, or individual labs could be selected and implemented based on a particular department's research focus. Setup movies were integrated into each lab to illustrate electrode or sensor setup. Real-time displays of raw and processed signals in the time and frequency domains and a user-friendly student database for saving and reporting results were added to each lab. A signal processing toolbox lab was also added.

A true 3rd generation electrophysiology lab[4] was created with examples of abnormal clinical phenomena and the clinical applications labs included. Advanced physiology laboratories expanded students' understanding, as examples of abnormal clinical data were presented for several disorders. For example, in the advanced EEG II lab, a database of abnormal clinical EEG signals are included and can be analyzed in time, frequency, or joint time-frequency domains (Figure 3).

Positive feedback was obtained after the course was integrated into the curriculum at several universities. "I am a first year professor, and to have CleveLabs here is wonderful."[5]

"My experience using CleveLabs was nothing less than a pleasure. The system is easy to use, and the students were learning the software quickly and efficiently… Students had good quality recording of EMG, EOG, and alpha-waves."[6]

IV. DISCUSSION

Undergraduate BME & HS programs are some of the fastest growing programs in the world; this requires innovative tools to properly train BME & HS students for applied clinical problems. Exposing BME & HS students to biomedical basics and practical applications of physiology better prepares them for careers in clinics, in research, or in industry.

The developed lab course incorporated learning styles shown to work best for BME & HS students including active, sensing, visual, and global learning styles. Active learning is employed since students are able to process information while completing a lab activity. Visual learning is utilized with the scrolling real-time data displays. The hands-on experience with cutting edge technology promotes sensory learning. Finally, global learning is incorporated as students understand the big picture in the terms of real-world applications.

The CleveLabs system was easily customized to fit department needs. Using the developed driver interfaces, professors and students can develop their own real-time lab sessions. CleveLabs provides students with an understanding of basic data principles and physiology, and the knowledge of how these principles fit into the big picture of clinical and rehabilitation needs.

V. ACKNOWLEDGMENT

We thank Gerald Loeb, Robert Glassman, and Berj Bardakjian, and Dmitri Kourennyi. Their conscientious assessments and insights were invaluable to course development.

---

[1] Gewin, V. "Biomedicine meets engineering", NATURE, Vol. 425, September, 2003, pp. 324-325.
[2] Meyers, C. and Ernst, E. "Restructuring engineering education" A focus on change, " Division of Undergraduate Education Directorate for Education and Human Resources, National Science Foundation, Report on NSF Workshop on Engineering Education., 1995.
[3] Dee, K.C., Nauman, E.A., Lievesay, G.A., and Rice, J. "Research Report: Learning Styles of Biomedical Engineering Students", Annals of Biomedical Engineering, Vol.30, pp.1100-1106, 2002.
[4] 1st generation being the development of instrumentation amplifiers to measure physiological signals; 2nd generation being the use of manufactured table-based electrophysiology equipment without inclusion of clinical applications.
[5] Joseph V Tranquillo, PhD, Biomedical & Electrical Engineering, Bucknell University.
[6] Dmitri E. Kourennyi, PhD, Assistant Professor, Biomedical Engineering, Case Western Reserve University.