
AC 2012-5208: BIOELECTRICAL INSTRUMENTATION: CONNECTIONS WITHIN INTERDISCIPLINARY ENGINEERING EDUCATION

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Bioelectrical Instrumentation: Connections Within Interdisciplinary Engineering Education

Abstract

Direct learning laboratory experiences are important to the future development of engineering student's capabilities. This work explores the implementation of bio-potential signal acquisition by students where their own bodies produced these signals. Their attitudes regarding the bio-inspired instruction and experiences were quantified anonymously and reported. Students ranked this experience positively as productive yet their responses demonstrated a need for the development of new content that emphasizes the engineering basis and physical dependence of the signals acquired.

Introduction

A challenge within interdisciplinary engineering education is directing the student focus out of their traditional or "home" discipline and across the multi-dimensional structure of new curricula. This challenge is particularly active at this institution within new courses emerging in response to an increased focus on engineering with a biological perspective. The objective in this case was to explore the use of and extensions facilitated by an integrated instrumentation platform. This platform permits students to perform bioelectrical measurements using their own bodies as the subject of laboratory instrumentation investigations, also known as active or project-based learning^{1, 2}.

The instrumentation platform utilized components from Biopac Systems, Inc., including: an amplifier module suitable to explore surface potential signals as low as micro-volts, surface electrodes to pickup such signals, apparatus to quantify skin response, respiration effort transducers, and software to facilitate signal visualization, guide the student(s) through a procedure, ensure proper calibration, and provide a format to encourage structured extension and exploration by the student(s) from a basis topic under study.

The exploratory course utilized for this work was Bioelectricity, offered to both undergraduate and graduate students in Electrical Engineering and Biomedical & Chemical Engineering Departments. Past offerings were limited to only lecture and therefore the electro-physiology concepts were described but could not be directly demonstrated. In the modified course the data to be quantified herein were obtained from laboratory experiences based upon the model instrumentation experiences developed by the equipment vendor. The instrumentation required little entry background and permitted students with little to extensive experience to acquire and quantify signals independently. Seven specific experimental lesson procedures grouped as EMG, ECG, EEG, and SCP were performed by teams of students. Each team included both graduate and undergraduate students, many of whom were from different departments. The majority of students, ~90%, had never observed electrical signals acquired from their own body.

Assessments in the form of post-experiment questionnaires with analysis to quantify the detail and structure of student work and understanding were performed. These results were explored from the perspective of extending this instrumentation approach to a broader offering of interdisciplinary courses.

Methods

The active learning modules utilized in this study (BIOPAC Systems Inc., Goleta CA) were the BSL 3.7.7 Biopac Student Lab Lessons and Pro, where the system package contains Lessons that permit independent sequences of prescribed experiments by topic and Pro is the vendor term that refers to the software level provided with the apparatus. This software drives the hardware that acquires the bio-potential and other transducer or input data provided by an MP36 instrument console. In addition a MANBSL377 Student Laboratory Manual³ was provided to the student groups for reference during their laboratory time. Each group of students included at least one graduate student and undergraduate students. These groups were kept small, typically less than four to optimize access to the instrumentation and software platforms. Students exchanged roles periodically during each lesson so that they all were provided the opportunity to acquire data and configure the instrumentation as well as to serve as test subjects.

The lessons utilized were Electromyography I & II (EMG), Electroencephalography I & II (EEG), Electrocardiography I & II (ECG), and GSR & Polygraph (SCP). Each lesson included a brief, few pages, introduction with background, primarily from a physiology point of view³. The scripted lesson also provides many examples of typically obtained measurements. The approach appears one of eliciting mimicry on the students part, where the students are shown where to apply contacts to the skin, which leads to attach and where, how the corresponding acquired signal should appear, etc.. Also, canned calibration routines were presented to check the signal lines and the amplifier connections. Following acquisition, data analysis and report structures were provided for each lesson.

Each group was asked to provide a group report for each lesson. In addition, each student was asked to provide anonymous responses for each laboratory to the question matrix given in Table 1. Students were also surveyed as to their attitudes regarding this active learning approach,

Table 1: Post Laboratory Assessment

1. Background information connected potential measured with theory.
2. Software/Hardware calibration performed?
3. Factors defined for each measurement performed.
4. If average values were measured, you provided direction as to range of values to be computed.
5. The bio-potential measured was related to nerve activity.
6. The bio-potential measured was related to muscle activity.
7. The bio-potential measured was due to a combination of nerve and muscle.
8. The distance between measurement electrodes changed the signal observed.
9. Switching leads around changed the signal magnitude but not the value.
10. Adequate biological background was provided to complement the electrical topics.
11. Define the source of the potential observed and the reference.
12. How could you derive additional bio-potential information from this setup?
13. My engineering education provided ample background to understand the measurements performed in this laboratory experience.
14. Did you add to the measurement script.
15. The data/report interface was adequate to the scope of this lab.
16. Our group was able to modify the interface to suit our laboratory objective.

whether the laboratory measurements provided insights into bioelectricity that they did not gather from text or lecture, and whether such activities should constitute a standalone course or be maintained as a subunit of the lecture course.

This exploratory interdisciplinary laboratory experience was the first foray into direct measurements that promised enhanced involvement of the students given that the measurement subject was the individual learning the material ⁴, not another animal or physical electrical circuit. Specific student attitudes were anonymously obtained from each student, independent from their laboratory group, covering a range of topics from adequacy of the background materials provided and prior engineering training to measures that would attempt to test their ability to separate the sources of and factors influencing the bio-potentials that they had measured. All surveys were administered following their experience in each laboratory and utilized measures on a five point scale from 5-Strongly Agree to 1-Strongly Disagree. Before the time that students participated in the laboratory they had studied and discussed the fundamentals of the Hodgkin Huxley models for nerve bio-potential development ⁵. Action potentials associated with nerve and muscle ⁶ had been introduced along with the underlying fundamental experiments and theory associated with such signal production.

Results

Students were asked their opinion regarding the adequacy of the laboratory manual background information in connecting the potentials measured with theory, Table 1 number 1. The characteristics appear, shown in Figure 1, in the form of the box chart, where \square = average, whiskers- minimum and maximum = \times , top of box -75% and bottom - 25%. The horizontal bar in the middle of the box is the median value. The results suggest that among these engineering students, ~80% electrical and ~20% bio-medical and chemical, the majority agreed with the statement for the electromyography, EMG1, and surface conduction velocity/polygraph lessons, SCP1. Clearly the broadest variation was for the electroencephalogram lessons, EEG1, and implied a significant level of uncertainty on the student's part. These results are likely associated with the focus of the lab manual supporting physiology study and not engineering. Most of the students in this course had taken basic laboratories supporting the performance of potential measurements but they likely had not thought much about the measurement of signals acquired on their own person. Such issues may be addressed with additional lessons that introduce the signal acquisition and magnitude factors using voltage/current sources and standardized circuits that the lab equipment could measure. This assumption is further supported by the distributions shown in Figure 2, where again students displayed a range of response but on average their opinion was that their engineering training supported their ability to perform the lessons. The broadest distribution of results, however, were again obtained for the EEG lessons.

Questions 5 through 7 of Table 1 address the students understanding, following the lessons, of the origins of the bio-potentials that they had measured. The distributions obtained, Figure 3, demonstrate that they associated muscle signals with myogram, EMG6, and cardiograms, ECG6. Further nerve signals were most strongly associated with encephalogram signals, EEG5. However, they exhibited uncertainty as demonstrated by the size or range of distributions to their answers to question 7 that suggested that the signal was due to a combination of both nerve and muscle. This may indicate that a clear separation between innervating signals from nerves and the muscle derived signals was not evident in the student's understanding of the topic.

Separately, 100% of student responses correctly identified the source of the bio-potential and its reference for SCP and EEG lessons. Further, a majority, 75% for EMG and 87% for ECG lessons respectively correctly enumerated the dominant source for the bio-potentials acquired in those lesson groups.

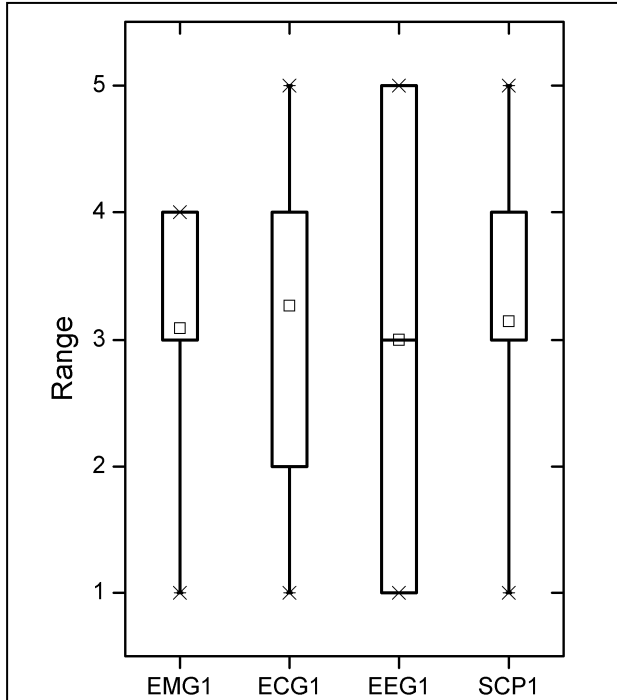


Figure 1. Box chart distribution results of student attitude regarding linkage between background information provided and actual biopotential measured. Legend of Laboratory Content: EMG = Electromyography, ECG = Electrocardiography, EEG = Electroencephalography, and SCP = Surface Conduction/Polygraph.

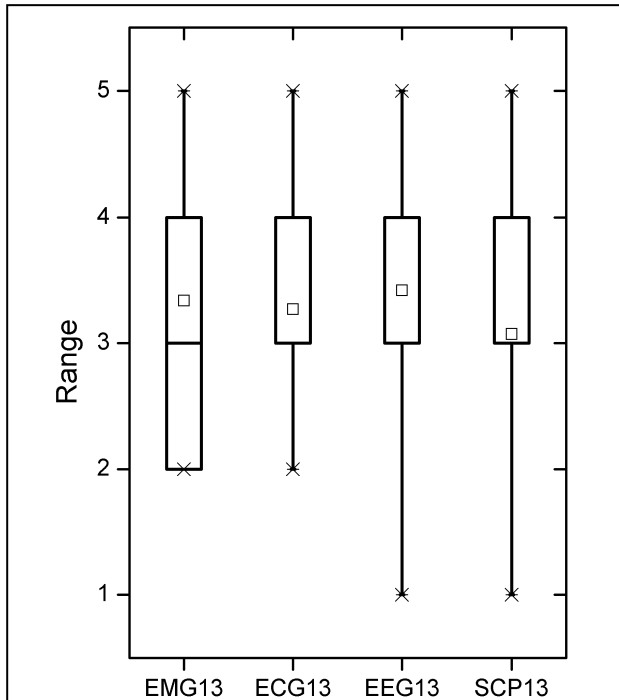


Figure 2. Distribution of survey results to engineering preparation adequacy to understand the measurements performed in laboratory. By lesson grouping as in Figure 1.

The distribution of student responses to the statement that the laboratory lessons provided insights into bioelectricity that were not acquired from text or lecture is shown as group S14 in Figure 4. Half of the students agreed or strongly agreed with this statement. Whether active learning or direct participant involvement as a component of the “circuit,” played a role in this result has not been determined at present. The students were rather equally distributed in their attitude regarding the separation of such experiences into a separate laboratory versus having them continue as a component of a larger lecture as shown in S15 of Figure 4.

Conclusions

Overall, students enjoyed and appreciated the lessons provided. Many commented that the interface was very inflexible and that they would have liked to have access to the background information and more details associating the signals acquired with physical quantities. As this

was a first time experience for all students, the range of responses was to some degree anticipated.

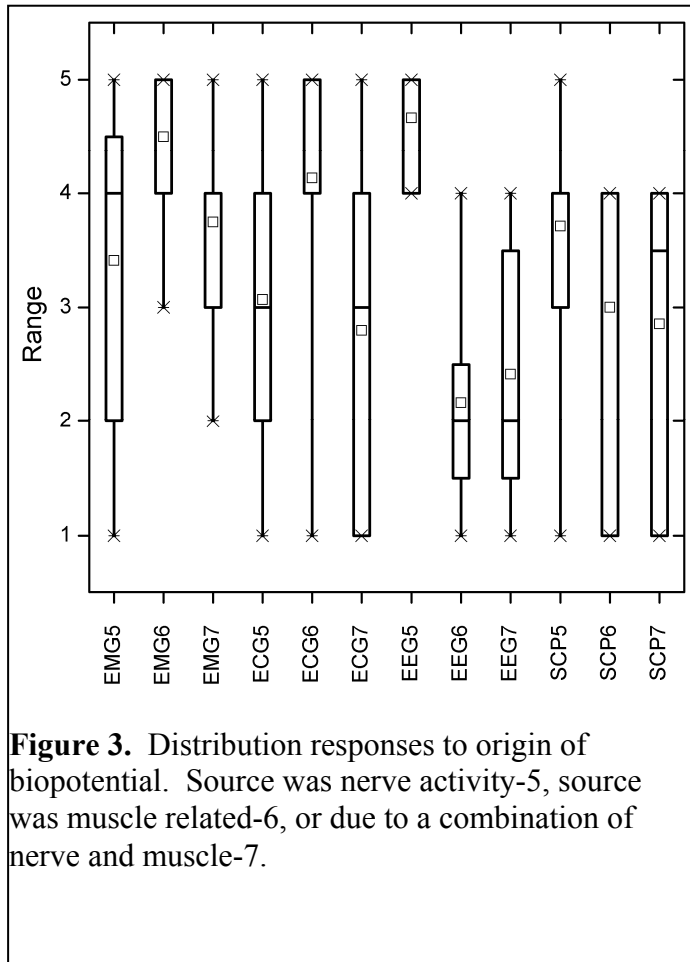


Figure 3. Distribution responses to origin of biopotential. Source was nerve activity-5, source was muscle related-6, or due to a combination of nerve and muscle-7.

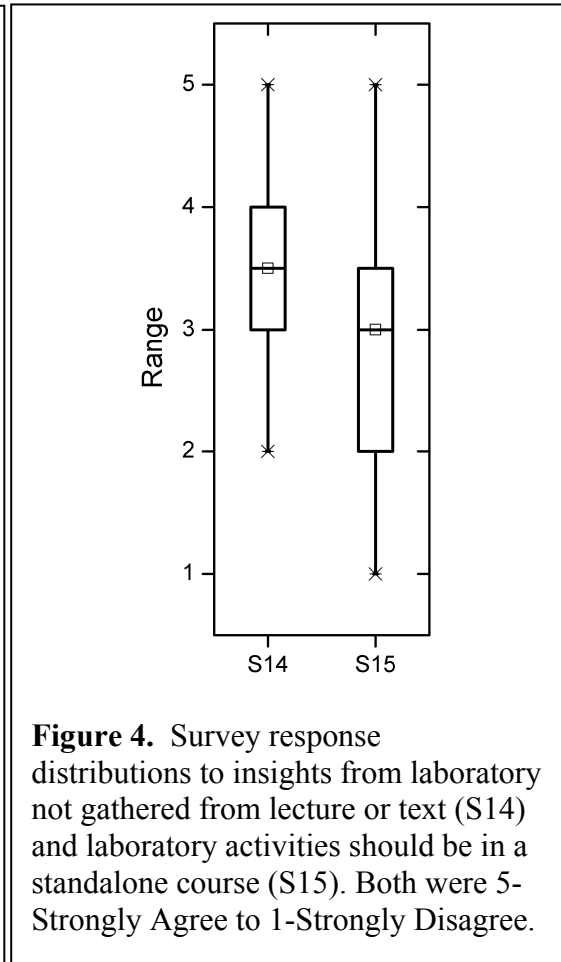


Figure 4. Survey response distributions to insights from laboratory not gathered from lecture or text (S14) and laboratory activities should be in a standalone course (S15). Both were 5-Strongly Agree to 1-Strongly Disagree.

The lessons learned from this study will further impact our programs for many years to come. Engineering students, at present, require a level of specification that was not present in the lessons provided. This is not a criticism of the vendor, as the system performed to expectations. In the author's opinion, modifications are necessary to the lessons and to the interface that the students engage. A more open authoring and control system would permit increased flexibility from the laboratory experience designer's perspective. Numerous instrument vendors have entered this market, mostly for physiology training, and each have an array of capabilities. For the purposes of utilizing such instrumentation in the bioelectricity course, an ideal system would easily enable modification to the student interface and pre-laboratory and laboratory sequence materials. Further, new lessons must be created that isolate signals such that the students may correlate the magnitude and sign of the signals obtained with calibration standards that could not have been part of the present study.

In order to disseminate this capability across single or multiple departments, within or outside of this institution, such that the hardware investment is spread over a larger user base, a bio-potential acquisition system should be easy to modify to suit an array of instructional or

discipline needs. Newly available hardware enables very powerful analysis of signals acquired far beyond the scope of this initial exploration. Such capability will facilitate laboratory module development to support instruction in courses such as introductory and advanced numerical methods, signal theory, circuits, cardiac modeling, controls, digital signal processing, advanced logic design, and systems development such as brain-machine interfaces and a number of other exciting instructional avenues.

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