AC 2008-1706: INTEGRATED LECTURE-LAB APPROACH WITH VIRTUAL INSTRUMENTATION FOR TEACHING ELECTRICAL CIRCUITS TO BIOENGINEERING STUDENTS

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Integrated Lecture-Lab Approach With Virtual Instrumentation For Teaching Electrical Circuits to Bioengineering Students

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Abstract

Teaching a first course on electrical/electronic circuits to bioengineering students with no previous background poses a significant challenge. An integrated lecture-lab approach is being developed at Florida Gulf Coast University with the incorporation of the ELVIS (Educational Laboratory Virtual Instrumentation Suite) workstation from National Instruments and its virtual instrumentation package, in addition to the traditional set of instruments. The initial experience indicates that integrating laboratory practice and lecture can increase student motivation and interest, particularly in the case of those bioengineering students not inclined towards the instrumentation line. Utilization of the NI ELVIS has been in general terms well received by students. This paper focuses on describing the initial experience of developing a new comprehensive and balanced introductory electrical circuits course in an undergraduate bioengineering curriculum using an integrated laboratory-lecture method and utilizing the aforementioned virtual instrumentation resource.

Introduction

Within the framework of an undergraduate bioengineering curriculum, teaching a first course on electrical/electronic circuits to students with no previous background presents a significant challenge. Given the number of different multidisciplinary areas that a bioengineering student needs to cover in his (her) training, a broad range of separate courses covering electrical circuits, electronics, and instrumentation has not been included in our curriculum. The first course on electrical/electronic circuits has to be highly comprehensive in nature, covering material traditionally taught through several courses to an electrical engineering major. In addition, given the many areas in the broad field of bioengineering, motivating those students with interest in areas other than electrical instrumentation, and who are taking the course as a requirement for their major, may not be an easy task. Therefore, finding an effective teaching methodology and using efficiently available supporting resources that help increase student motivation and learning are essential.

A junior level course on electrical/electronic circuits for bioengineering students was taught for the first time at Florida Gulf Coast University this past fall semester. An integrated lecture-lab approach was initiated and its development continues at the present time with the goal of increasing student learning. The ELVIS workstation from National Instruments with its virtual instrumentation package was incorporated in the teaching environment, in addition to the traditional set of instruments for circuit test and measurement. The ELVIS (Educational

Laboratory Virtual Instrumentation Suite) includes a physical hardware workstation, a data acquisition module, and virtual instrumentation software (Figure 1).

Use of an integrated lecture-lab approach to teach circuits in electrical engineering and general engineering majors has previously been reported by other authors with positive results [1,2]. Utilization of the ELVIS system in bioinstrumentation courses [3,4] as well as in several electrical engineering and electronics technology courses [5-8] has also been presented by various authors. However, experience with integrated lecture-lab and use of the ELVIS system to teach a first course on electrical/electronic circuits to bioengineering students appears novel. This paper focuses on describing the initial experience of developing a new comprehensive and balanced introductory electrical/electronic circuits course in an undergraduate bioengineering curriculum, using an integrated laboratory-lecture method and utilizing the ELVIS system with its virtual instrumentation package.

Course and Content

This course, Circuits for Bioengineers, is a 3 credit first electrical/electronic circuit course at the Junior level in the undergraduate bioengineering major and the first course in a required instrumentation sequence that also includes the subsequent courses Signals and Systems for Bioengineers, and Biomedical Instrumentation. The course is required for all bioengineering students, regardless of the students' specific line of interest. Prerequisites for the course include Calculus II, General Physics II, and a freshman level Problem Solving and Design for Engineers course (which includes MATLAB® programming).

Course topics covered have included:

- Resistive networks,
- network theorems,
- energy storage elements,
- first order transients in linear circuits,
- transients in second-order circuits,
- sinusoidal steady state circuit analysis, and an
- introduction to electronic circuits, including
    - basics of MOSFETs and BJT devices,
    - the operational amplifier, and an
    - introduction to digital circuits.

Integrated Lecture-Lab and Use of the ELVIS System

The course was taught for the first time last fall of 2007 to a pilot group of five students that had reached the Junior level. Class met twice a week for a period of 2 hours and 15 minutes each time. The basic approach was to distribute the time to have an initial lecture or exercise session followed by a practical laboratory session within that 2 hour and 15 minute period. Depending on the nature of the various topics and the need for more theoretical exercise and problem sets, or more practical bench work, some class sessions became purely theoretical or purely laboratory practice, but the approach of integrating lecture and lab in the same class session became the rule. The classroom used had students sitting around large tables facing whiteboards and projection for presentation of fundamentals, and for working problems, with lab stations set up across the rear of the room (Figure 2). Laboratory sessions were included in half the classes.

Specific laboratory sessions included:
- Familiarization with traditional instruments: oscilloscope, function generator, power supply (1 session)
- Circuit equivalent resistance testing/verification (1 session)
- Kirchhoff's laws and resistive network analysis (2 sessions)
- Bipolar junction transistors and amplification (2 sessions)
- First order transients – response of RC and RL circuits (2 sessions)
- Transients in second order circuits –RCL circuits oscillatory behavior and damping (2 sessions)
- Sinusoidal steady-state analysis: frequency response, resonance, filters (3 sessions)

In the first lab sessions, students used a prototyping board and the traditional set of instruments: oscilloscope, power supply, and signal generator (Figure 3). The ELVIS system was mainly used towards the last part of the course, when the students were comfortable with the use of the traditional instruments and four ELVIS stations were set up so almost all the students had individual stations. The specific modules for which the students use the ELVIS system were:

Transients in second order circuits (1 session)
Sinusoidal steady state: Frequency response, resonance, filters (2 sessions)

An example of work carried out by the students with the ELVIS package, involving circuit frequency response and basic filters, is shown in Figures 3, 4, and 5. In this case, the traditional set of instruments was also used in the analysis of the same circuits for comparison (Figure 3). During some laboratory sessions, the students work specifically with the ELVIS, and in other sessions they work with the traditional set of instruments. Normally, they did not work with both types of equipment at the same time because it was not considered necessary and there were time constraints. Nevertheless, the students had experience with both in the same study modules.

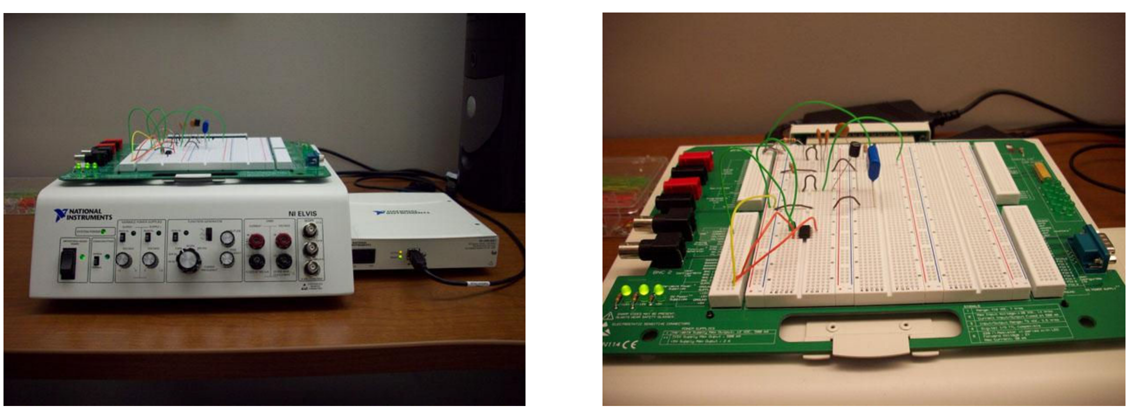

Figure 1. NI ELVIS benchtop and prototyping board with RCL filter circuit under test

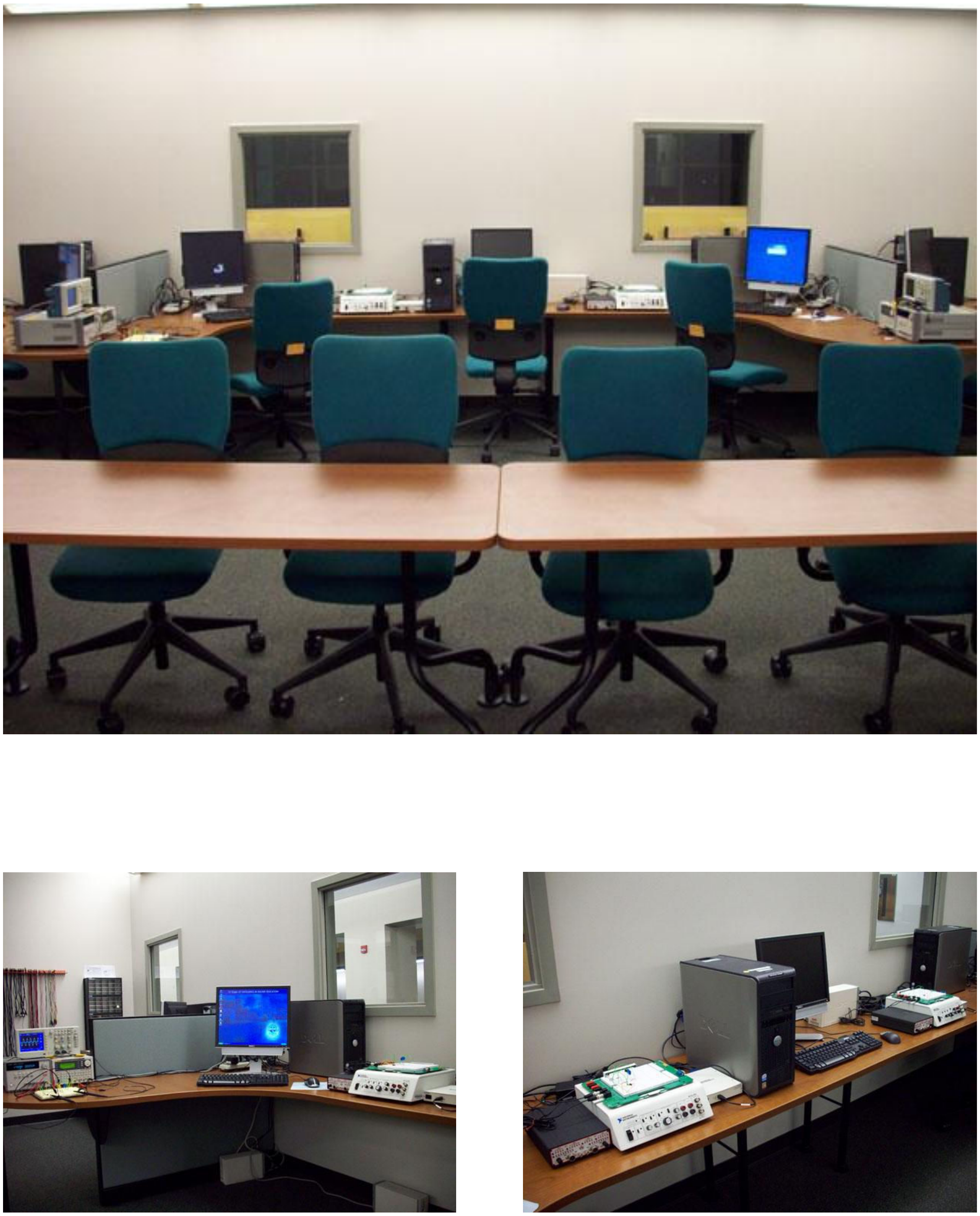

Figure 2. Setting for integrated lecture and laboratory in the same room

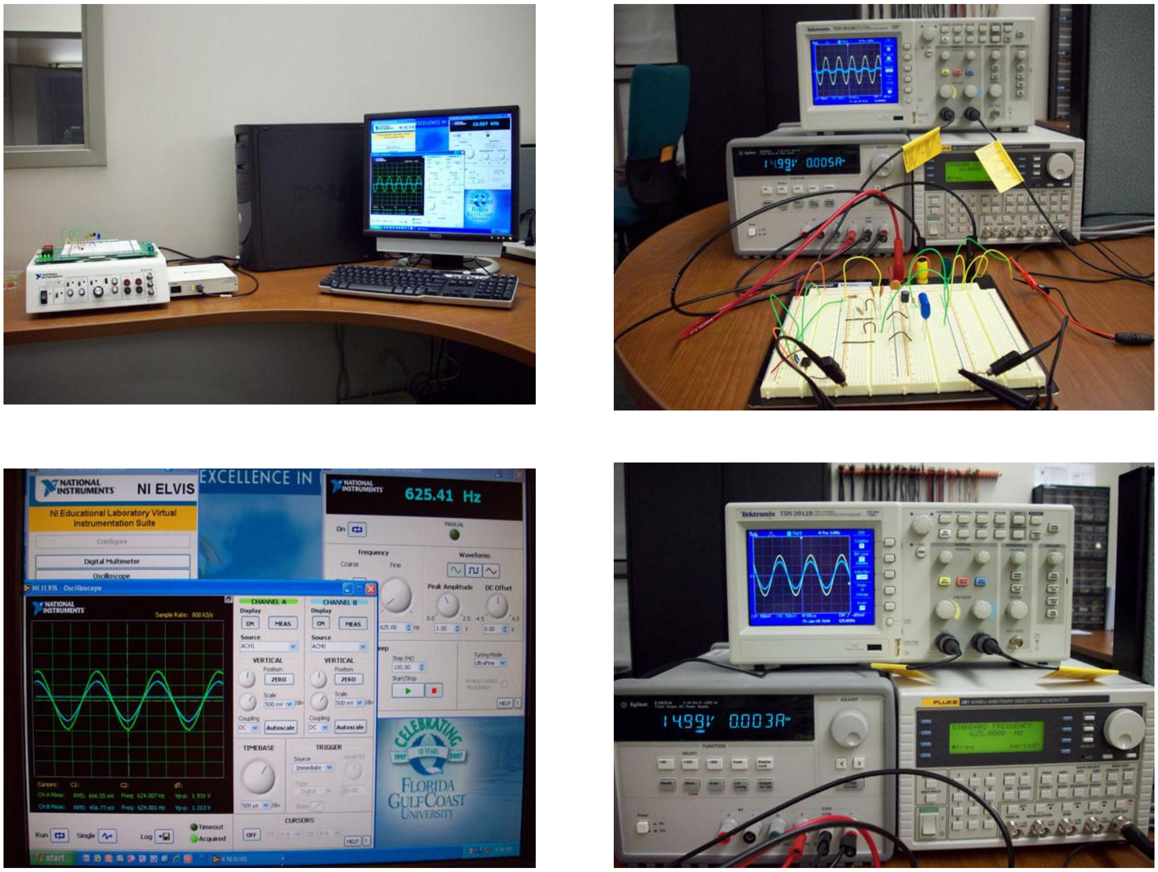

Figure 3. NI ELVIS workstation vs traditional set of instruments. Same circuit is used on each prototyping board and same graph appears on both oscilloscopes

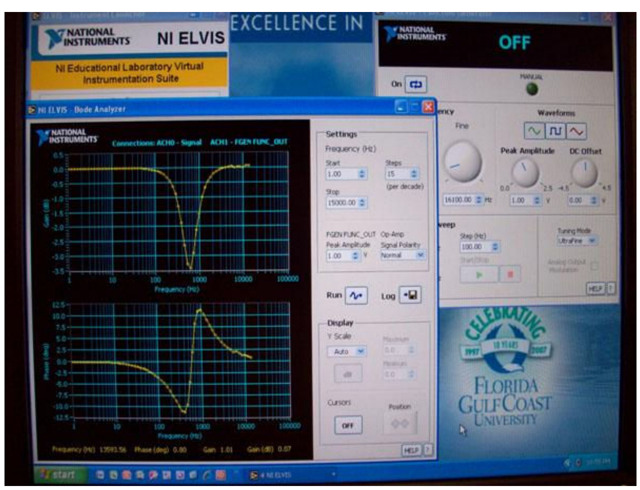

Figure 4. Bode plots obtained with the ELVIS software for the RCL filter circuit being tested

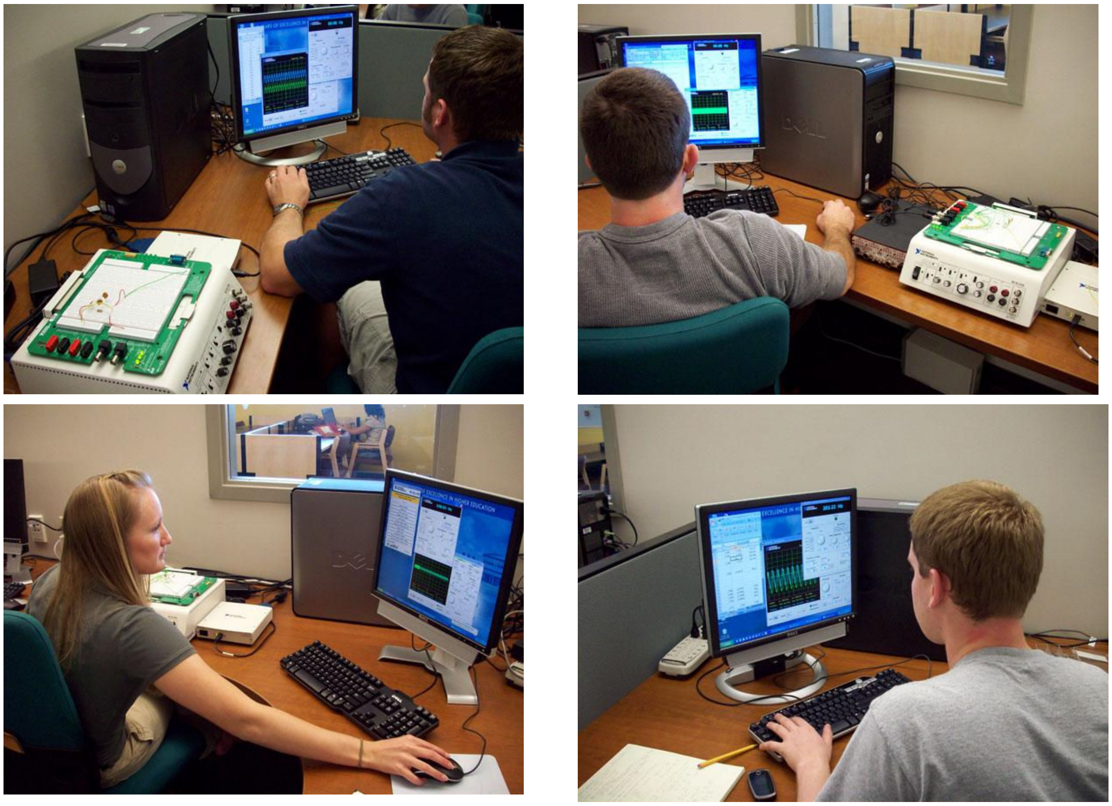

Figure 5. Students working on lab practice on individual ELVIS workstations

This initial experience with a small group of five students was very positive in indicating that integrating laboratory practice and lecture increased student motivation and interest, as judged qualitatively (by the instructor) by the students' increased class participation, attention to details, and eagerness to match practical and theoretical results.

In a short and simple survey, the students were asked to grade their interest in electrical/ electronic instrumentation using a score from 1 to 5 and answer the following question: "Do you consider that the integrated lecture-lab approach helped you understand better the material and increased your motivation for the course?" Their responses are presented in Figure 6 below.

Interestingly, the scores for their interest in electrical/electronic instrumentation were distributed uniformly across the 1 to 5 range. The four students that gave themselves the scores 1 to 4 answered YES to the question, but raised their high concern about the time allocated for the lab practice. In fact, they insisted that their positive view of the integrated lecture-lab had attached the condition that the lab practice had a minimum time duration of 1 hour and 30 minutes out of the 2 hours and 15 minutes allocated for the session. That corresponds to 2/3 of the total time. They insisted that they disagreed with the shorter time which was given in some of the sessions that covered more theory. The student who indicated high interest in the instrumentation line (giving himself a score of 5) and answered NO to the question, insisted in his preference for a separate full session of lab practice with time to prepare after the lecture on the topic. In an integrated lecture-lab approach, all five students agreed that they preferred a short lecture followed by a longer session of exercises one day of class and a short lecture followed by a lab practice the following day of class.

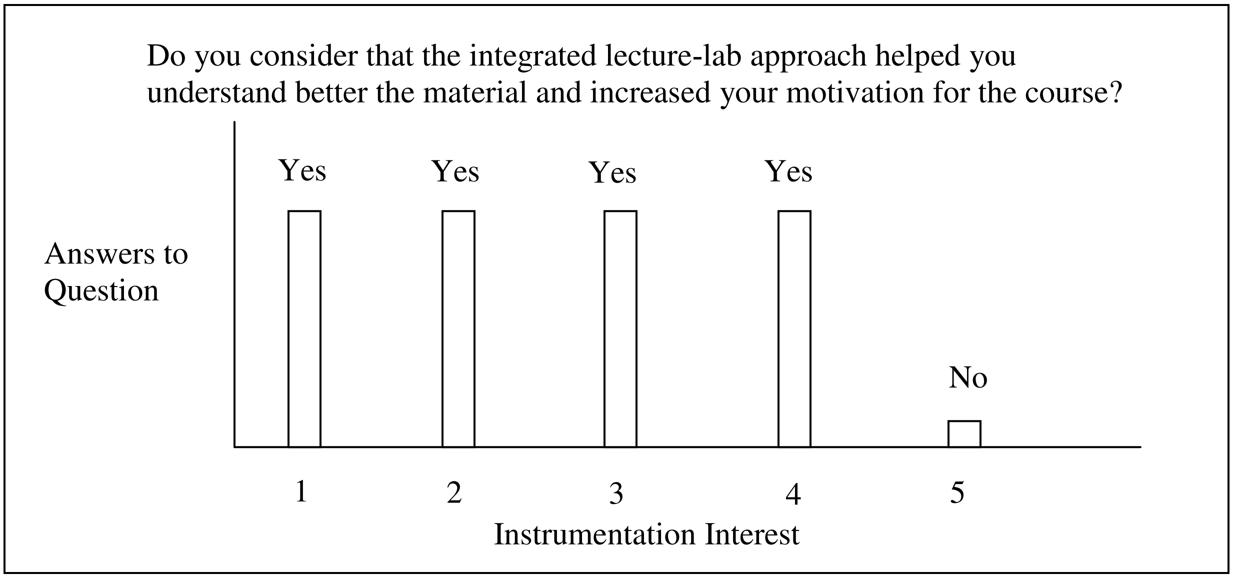

Figure 6. Answers to the indicated question. The X axis contains the score the students gave themselves for their interest in instrumentation.

Utilization of the ELVIS system was well received by the students and their response was positive in general. In a short survey, they expressed their view on positive and negative aspects of the system. On the positive side, they mentioned the following reasons:

1. It's easy to use once one gets familiar with it.
2. It's good to have access to and manipulate various virtual instruments using the same software package.
3. It's appealing to use the ELVIS computer graphics interface for lab practices.
4. It allows direct storage of data in the computer for further use with other applications.
5. The Bode analyzer (Figure 4) is a very useful feature to automatically create Bode plots for circuit frequency response and directly store the corresponding data. (Note: students did have to work their own Bode plots with data obtained using the traditional set of instruments prior to the use of the ELVIS system for this purpose.)

They did point out some disadvantages:

1. Some features are slow to respond.
2. There is a lower precision in setting input values and lower accuracy is some output parameters when compared to traditional measurement instruments.

The students were also asked the following question: “What system (equipment) do you prefer to use in future lab practices for the subject modules in which you have previous experience using both the ELVIS and the traditional set of instruments?” (As indicated previously, those modules included transients in second order circuits and sinusoidal steady state analysis.) The answers are shown in Figure 7 below.

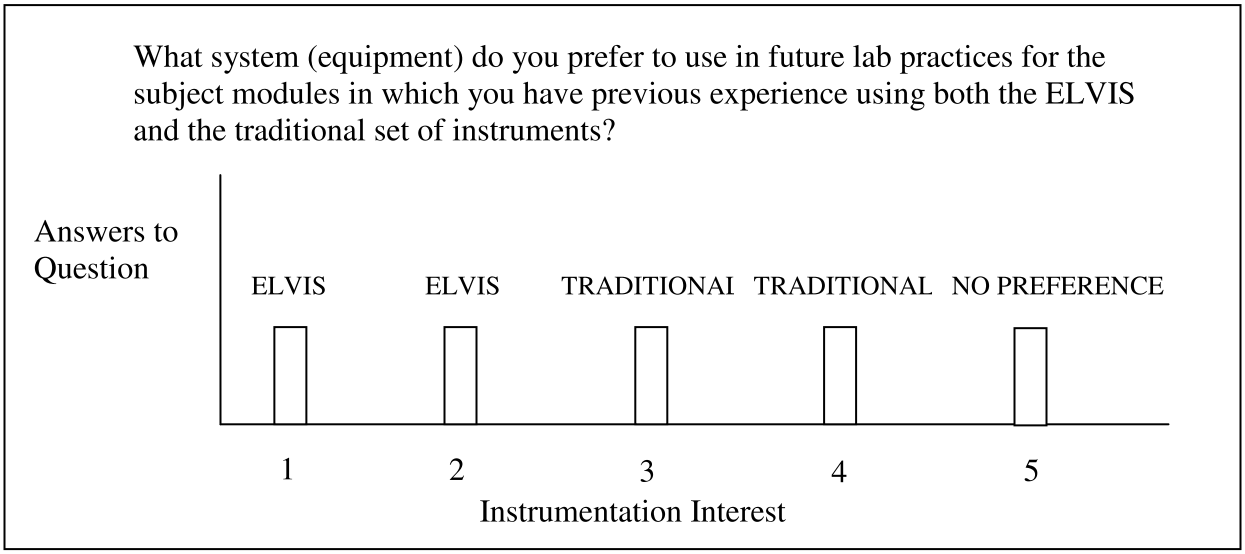

Figure 7. Answers to the indicated question. The X axis contains the score the students gave themselves for their interest in instrumentation.

The ELVIS system will continue to be used in a subsequent senior-level Biomedical Instrumentation course and in additional courses that require acquisition of biomedical signals such as our Signals and Systems for Bioengineers and Human Physiology courses. The three courses that build depth in electrical measurements and instrumentation, i.e. Circuits for Bioengineers, Signals and Systems for Bioengineers, and Biomedical Instrumentation, are being developed in such a way that there is good continuity of the material throughout the sequence.

Conclusion

Initial experience with a small group of five bioengineering students that first took an electrical/electronic circuits course at Florida Gulf Coast University indicates that integrating laboratory practice and lecture in classes for this particular course increased student motivation and interest, particularly in the case of those bioengineering students not inclined towards an electrical/electronic instrumentation line. Utilization of the NI ELVIS system has been well received in general by the students, even at this early stage of learning in circuits and electronics, as they easily relate to the computer graphics interface of the various virtual instruments and welcome some of the software capabilities such as direct storage of data in their computers for further use in other applications. The system is also being used for signal acquisition in our

Signals and Systems for Bioengineers and Human Physiology courses that are being taught this spring semester and will be incorporated also in the subsequent Biomedical Instrumentation course to be taught next fall semester.

Acknowledgement

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