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# **AC 2011-1249: INCORPORATING STUDENT-OWNED PORTABLE INSTRUMENTATION INTO AN INTRODUCTION TO ELECTRICAL ENGINEERING COURSE**

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# **Incorporating Student-owned Portable Instrumentation into an Introduction to Electrical Engineering Course**

A new approach to hands-on instrumentation has been adopted into the Introduction to Electrical Engineering course for first year students. Students purchase the National Instrument (NI) myDAQ unit and bring it with them to lab to perform DC circuit experiments. Through this device students are not limited to experimenting with circuit in the laboratory, but are able to create and analyze DC circuits in the comfort of their own room using their personal computer or in any of the departmental computer centers on campus. This allows students to test out basic circuit theory learned in textbooks or in the classroom anytime and anywhere which enhances their learning experience. A hands-on learning experience of electrical engineering concepts is available at a low cost. Through the use of the LabVIEW program students learn to create virtual instruments that they can interface through the NI myDAQ with the physical world to form their own customized laboratory. Preliminary results of the course will be discussed, as well as plans to utilize the device in subsequent courses.

## **Introduction**

This paper introduces a new approach to an introduction to electrical engineering course for first year students at The University of Texas, Austin. The classical concept of going to a lab at the university and doing the required set of labs has changed due to an adoption of a new hands-on instrument called the NI myDAQ. The following sections, present an overview of the course curriculum, as well as what the NI myDAQ device is and important specifications are shown, followed by a summary of the students' response to a first semester trial of the lab change. Future implementation plans will be shared.

## **The Introduction to Electrical Engineering course Course Curriculum**

The Electrical and Computer Engineering Department at The University of Texas, Austin originally created the Introduction to Electrical Engineering course (EE302) about 15 years ago so that students would have a course in their major during their first semester on campus. Prior to the creation of this course, many ECE students did not take the first ECE course until the second semester of their sophomore year and focused instead on the math and science prerequisites. Some students lost interest in ECE before they had the opportunity to take the first course. Over time, the course evolved from a survey course that superficially covered many aspects of electrical and computer engineering into a course focused on building competence in DC circuit analysis. Later, two other courses were added to the first year ECE program focused on computing and embedded systems. The DC focus of EE302 is necessary because some students have not yet taken a calculus course. EE302 includes a two hour weekly lab so that the students have a hands-on experience with the concepts covered in lecture.

EE 302 is broken into two main components. The first component is a survey of important aspects for the Professional Engineer. The topics covered include the following:

- Different focus areas in electrical and computer engineering
- Problem solving and the Engineering Design Process

- Ethical behavior of engineers
- Responsibilities of the engineer to society
- Skills for continuing education and independent study

These topics are covered primarily by a series of short reports completed throughout the semester.

The second component focuses on the analysis of DC linear circuits covering the following topics:

- Physics Representation of Analog Circuit Quantities
- Definitions of analog circuit elements such as resistors, voltage/current sources, and dependent sources.
- Kirchhoff's Current and Voltage Laws
- Advanced circuit analysis techniques such as node voltage and mesh current analysis
- Development of Thévenin and Norton equivalent circuits for analyzing circuits
- Creating and using models for advanced electronic devices including diodes, transistors, and op-amps.

The weekly lab assignments are designed to reinforce the student's knowledge of the lecture topics and are an integral component of EE 302. The laboratory problems have been designed to encourage students to take advantage of computer applications and other tools available in the laboratory. Although this is not a programming course, students are expected to develop both expertise and confidence in using computers to solve technical problems.

At the end of EE 302, students are expected to:

- Understand the relationships between current, voltage, energy, and power
- Be able to draw accurate schematics of DC circuits
- Be able to solve for specified quantities in DC linear circuits using the following techniques: Kirchhoff's Current and Voltage Laws; voltage and current division; node voltage analysis; mesh current analysis; and superposition
- Be able to build a circuit on a breadboard based on a circuit schematic and accurately measure currents and voltages from this circuit.

### **NI myDAQ: Mobile Personal Instrumentation Device**

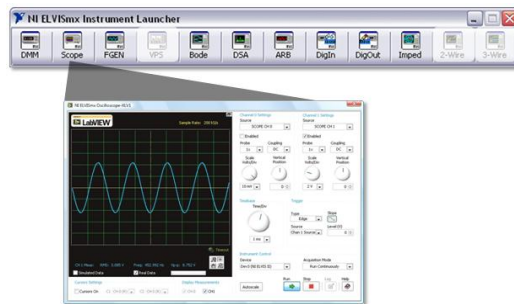
NI myDAQ is a low-cost portable data acquisition (DAQ) device that uses NI LabVIEW-based software instruments, allowing students to measure and analyze real-world signals (Fig. 1). NI myDAQ is ideal for exploring electronics and taking sensor measurements. Combined with NI LabVIEW on the PC, students can analyze and process acquired signals and control simple processes anytime, anywhere.



**Figure 1:NI myDAQ being used to probe the output of a Solar Cell**

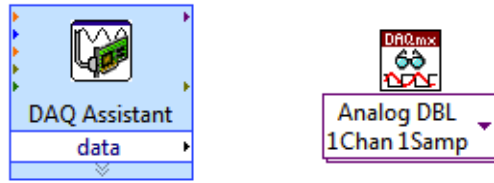
With an affordable, student-owned, instrumentation and control tool NI myDAQ, the students learning can be extended beyond the lab and lecture. Students can perform experiments anywhere, anytime for the cost of an engineering textbook (starting at \$175 USD for student purchase online).

Designed by National Instruments utilizing analog IC's from Texas Instruments, NI myDAQ provides a complete set of capabilities to learn circuits and measurements concepts. NI myDAQ also integrates with NI ELVISmx software-based instruments(Fig. 2) that include an oscilloscope, waveform generator, digital multimeter, power supply, digital i/o, and bode analyzer, all of which students can use to perform many laboratory-style experiments in the comfort of their dorm rooms. These same software instruments are integrated into NI Multisim, allowing students to compare their circuit simulations to actual measurements on the same display.



**Figure 2: NI ELVISmx Instrument Software**

In order to create custom experiments, NI myDAQ is fully programmable with NI LabVIEW. This allows students to move beyond the provided software-based instruments and create their own programs ( VIs ) to explore and understand a lab concept. The LabVIEW interface to NI myDAQ is available through the DAQmx driver, including both the DAQ Assistant and lower-level DAQmx Vis(Fig. 3). There are also a specific set of ELVISmx Express VIs(Fig. 4) which match the specific instrument functions of both NI myDAQ and NI ELVIS.



**Figure 3 : DAQmx VIs in LabVIEW**

 NI ELVISmx Arbitrary Waveform Generator	 NI ELVISmx Bode Analyzer	 NI ELVISmx Digital Reader	 NI ELVISmx Digital Writer
 NI ELVISmx Digital Multimeter	 NI ELVISmx Function Generator	 NI ELVISmx Oscilloscope	—

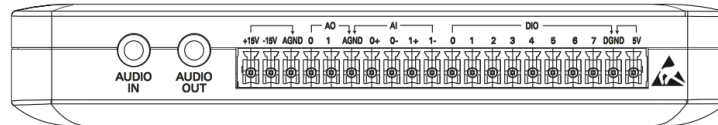
**Figure 4 : NI ELVISmx Express VIs in LabVIEW**

The specifications of NI myDAQ are designed to allow sampling and generation of analog signals through the audio range of frequencies. Digital lines are configurable as either output or inputs, and one line is reserved as a counter for pulse train input/output. Fixed power supplies allow students to power sensors or IC's on a breadboard. The total power available is governed by the USB bus and is limited to 500mW. The analog outputs may be used as a

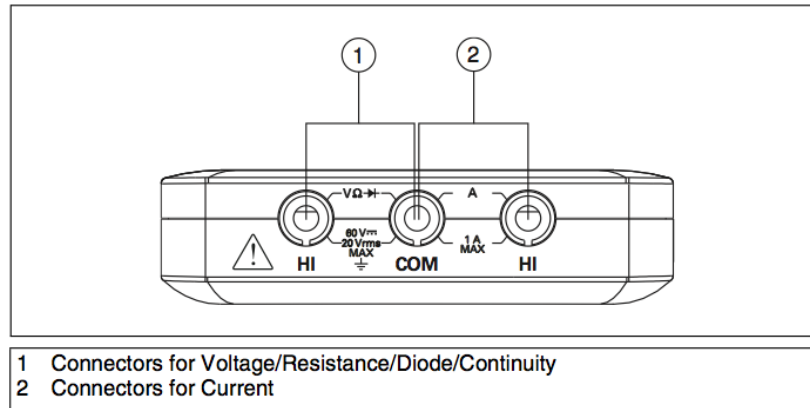
**Specifications:**

- Analog Input
  - 2 channels, 200kS/s, 16-bit
- Analog Output
  - 2 channels, 200kS/s, 16-bit
- Digital I/O: 8 lines
- Power Supply: Fixed +5V, +/-15V
- Screw terminal connectors(Fig. 5)
- Banana Jack for DMM(Fig. 6)
- Bus Powered (USB) operation

stimulus signal, but are limited to 2mA/channel. DMM banana jack inputs provide standard lab probe connections to the students' circuit. Connectors include screw terminal, banana jack, and 1/8" audio in/out.



**Figure 5 : Screw-terminal and Audio-jack connectors**



**Figure 6 : DMM Banana-jack Connectors**

## History of the Lab

Between 2002 and 2009, the EE302 lab included a team-based project using Lego Mindstorm Robot kits. In teams of four, the students designed the hardware configuration and software for an autonomous robot competition. This project took about seven weeks and concluded with the competition and a final oral report. The objective of this project was for the students to solve a design problem as part of a team and to confront the normal limitations and imperfections of real life hardware and software systems. They had to plan the project activities, divide up and manage the work over a period of several weeks, and integrate the resulting designs to produce a working system. For most students this is their first experience working in a self-managed team and their first experience with a design problem for which they were not given detailed step-by-step instructions. The primary advantage of the Mindstorm robots for this project was that the students did not need any of the lecture material to begin this project. Therefore, the project could be placed in the first month of the lab while the students were learning Ohm's Laws, Kirchhoff's Laws and other basic circuit concepts.

While the teamwork aspect of the robot project has been successful, the technical content gradually became uninteresting as Mindstorm robots were widely adopted in high school applications. Also, the hardware kits were worn-out and needed replacement. The need for the financial commitment to replace over 100 Mindstorm kits forced a review of the future direction of the lab component of the course. As a result, the decision was made to drop the robot competition and replace it with a new approach in which the students would purchase individually owned computer controlled instrumentation (NI myDAQ) that could be used in EE302 and also for future courses.

For the Fall 2010 semester the EE302 lab was modified as shown in Fig. 7 to be able to incorporate the use of the NI myDAQ in the lab. The Robotics lab portion was replaced with new

labs while the basic contents of the previous circuit labs were modified to utilize the NI myDAQ as the student's personal instrumentation device.

<b>Previous Labs (Before)</b>	<b>Fall2010 Labs (After)</b>
Lab 1: Robotics I (Team organization, Robot Maze)	Lab 1: Intro to Labview & myDAQ(Simple Task)
Lab 2: Robotics II (Project Planning, Robot Line Following)	Lab 2: Labview Program(Implement Multimeter)
Lab 3: Robotics III (Project Planning, Robot Line Following)	Lab 3: Circuits Lab I (Use Multisim to simulate resistive circuits and obtain voltages and currents)
Lab 4: Robotics IV (Implementation)	Lab 4: Circuits Lab II Breadboard and Measurements
Lab 5: Circuits Lab I (Build a circuit on a breadboard from a circuit diagram and measure voltages and currents)	Lab 5: Circuits Lab III (Analyze a Zener Diode Circuit)
Lab 6: Robotics V (Competition)	Lab 6: Circuits Lab IV - Solar Power (Conduct experiments on a solar power array)
Lab 7: Circuits Lab II - Solar Power (Conduct experiments on a solar power array)	Lab 7: Circuits Lab V (Soldering and kit building)
Lab 8: Robotics VI (Oral presentations)	Lab 8: Circuits Lab VI (Use lab measurements to verify Thévenin equivalent circuits.)
Lab 9: Circuits Lab III (Use Multisim to simulate resistive circuits and obtain voltages and currents.	Lab 9: Proficiency Exam
Lab 10: Circuits Lab IV (Soldering and kit building)	Lab 10: Audio Equalizer Lab
Lab 11: Circuits Lab V (Use lab measurements to verify Thévenin equivalent circuits.)	Lab 11: Circuits Lab VII (Build and analyze an op-amp circuit)
Lab 12: Circuits Lab VI (Build and analyze an op-amp circuit)	
Lab 13: Proficiency Exam	

**Figure 7 : EE302 Lab Curriculum Changes**

The use of the NI myDAQ in the labs for the Fall 2010 semester was mainly as a DMM. But the students actually used LabVIEW to program their personal DMM and continued to use it throughout the semester.

### Student Feedback Results

After the first semester of the initial launch of the NI myDAQ in the EE302 lab students(187 students replied) were ask to do a survey(7 questions, Q1-Q7) about their experience with NI myDAQ in the lab. The results are shown below (Figs 7-13).

Fig. 7 and Fig. 8 show that over 60% of the student's agreed that the use of the NI myDAQ aided in their learning experience and understanding of the practical aspects of engineering. But from Fig. 9, less than 50% thought they would continue to use it outside of class. This is due to the lack of use and motivation for the first semester using this device. The labs were basically the previous labs utilizing the NI myDAQ as the DMM. Modifications in future semesters with more practical and motivating labs, and also homework using the NI myDAQ is expected to bring more students to explore electrical engineering outside of the classroom. From Fig. 10 a little over 70% of the students thought the lab content was well balanced and from Fig. 11 close to 80% of the students gained proficiency in taking basic voltage, current and resistance measurement. From Fig. 12, a little over 50% of the students felt they were comfortable programming in LabVIEW. This is expected to improve by increasing the number of lectures on basic programming in LabVIEW. Already in the spring 2011 semester the current number of LabVIEW introduction labs are scheduled to increase to three lab sessions, which is an increase from one and a half in the fall 2010 semester. Finally Fig. 13 shows the students' opinion on the cost of the device and textbook bundle. Surprisingly, a little under 40% of the students felt the cost was a worthwhile investment. Resulting in the lack of motivating and engaging labs utilizing the NI myDAQ as more than a DMM. Without the realization of the merits of being able to have a laboratory setting in the comfort of the home and the saving of money from purchasing separate instruments such as an oscilloscope, variable power supply, spectrum analyzer and function generator. This is hard to expect from incoming engineering students but is expected that the students realize as they progress and mature as engineers.

From the survey results and feedback from students and TAs, the use of NI myDAQ in EE302 is in the process of maturing and is looking promising as a new educational tool to get students interested in about electrical engineering and motivated to take the concepts learned outside classroom.

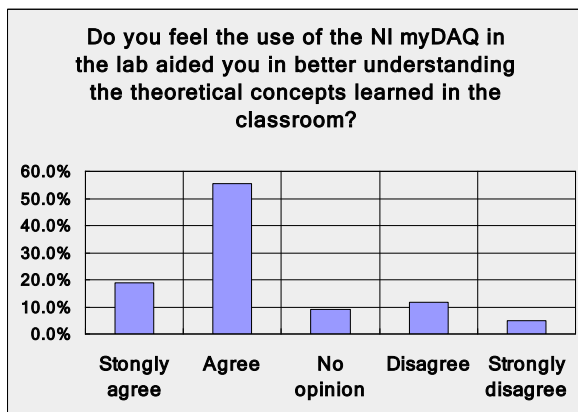


Figure 7: Q1 Result

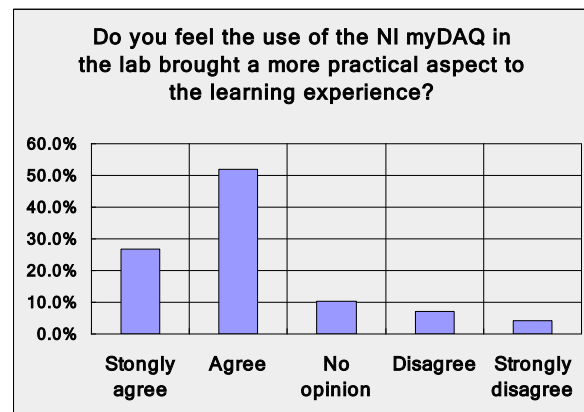
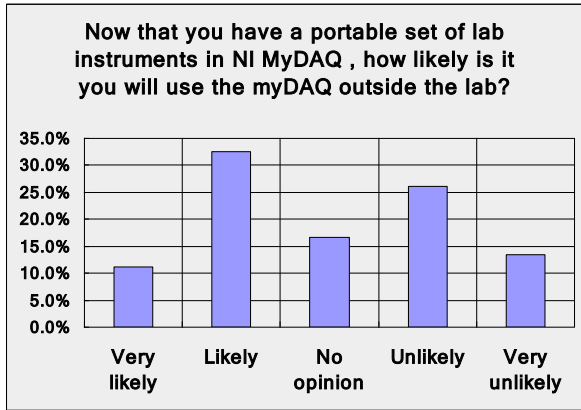
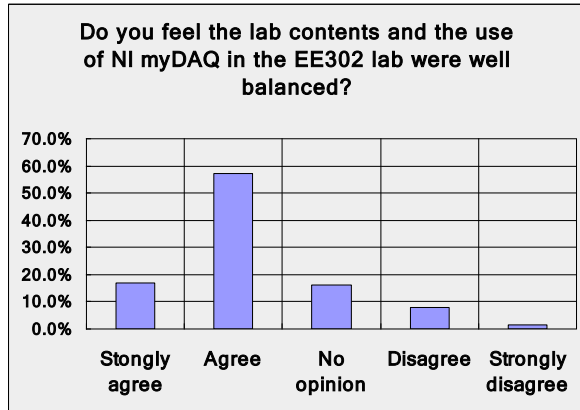


Figure 8: Q2 Result

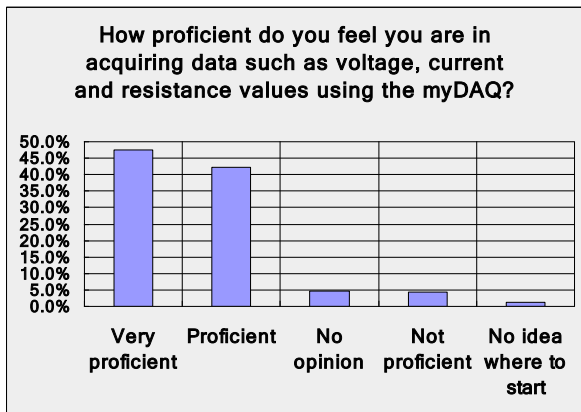




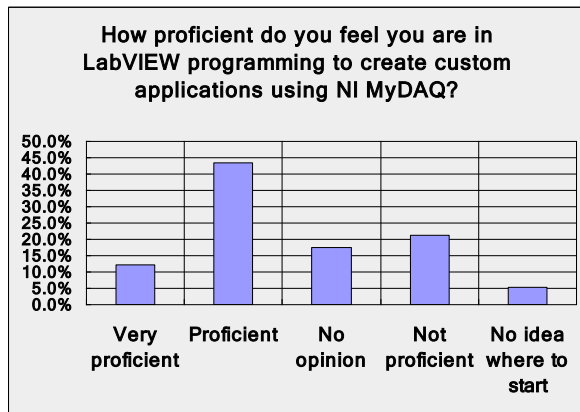
**Figure 9: Q3 Result**



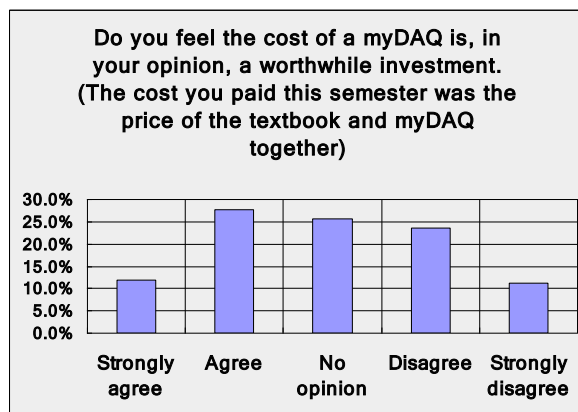
**Figure 10: Q4 Result**



**Figure 11: Q5 Result**



**Figure 12: Q6 Result**



**Figure 13: Q7 Result**

A slight change was done in the Spring 2011 labs (Fig. 14) and that was to increase the number of labs allocated to teach the freshman students on how to program simple vi's in LabVIEW. This increase has improved the student's response to the use of NI myDAQ as shown in Fig. 15. The Figures 15-16 were surveys done on students(7 students) in the middle of

retaking the EE302 course. Since they have experience with both the Fall 2010 and a slight experience with Spring 2011 lab their feedback provided important information about the use of NI myDAQ in the EE302 lab. Also some of the labs, for instance the Zener Diode and Solar Power lab were altered to utilize the NI myDAQ as more than a DMM. In these labs they used the NI myDAQ as I-V curve generators and also Data logging devices to get hands on experience of more advanced engineering techniques not requiring complex mathematical engineering concepts. This motivates the students to explore more on their own using the NI myDAQ as a handy tool with more functions than just a DMM.

One of the labs the students enjoyed the most was the Audio Equalizer lab. Without any knowledge of the frequency domain, complex mathematical topics like Fourier Transforms or Electrical Engineering concepts such as DSP and filter design, students used their NI myDAQ and LabVIEW to program a software version of an audio equalizer. Students plugged in their mp3 players (ex. Iphone) and adjusted the gain of different frequency ranges and heard the result through a speaker or earphones. This lab provides a platform for students continuing into advanced courses in EE to get a head start and obtain a valuable intuition on future topics.

<b>Spring 2011 labs</b>
Lab 1: <b>Intro to LabVIEW 1</b>
Lab 2: <b>Intro to LabVIEW 2</b> & myDAQ(Simple Task)
Lab 3: <b>Intro to LabVIEW 3</b> (Implement Multimeter & Variable voltage source)
Lab 4: Circuits Lab I (Use Multisim to simulate resistive circuits and obtain voltages and currents)
HW Review
Lab 5: Circuits Lab II Breadboard and Measurements
Lab 6: Circuits Lab III Zener Diode – <b>Building Curve Tracer</b>
Lab 7: Circuits Lab IV - Solar Power – <b>Data Logging</b>
Lab 8: Circuits Lab V (Soldering and kit building)
Lab 9: Audio Equalizer Lab
Lab 10: Circuits Lab VI (Use lab measurements to verify Thévenin equivalent circuits.)
Lab 11: Proficiency Exam
Lab 12: Circuits Lab VII (Build and analyze an op-amp circuit)

**Figure 14 : EE302 Lab Curriculum Changes for Spring 2011**

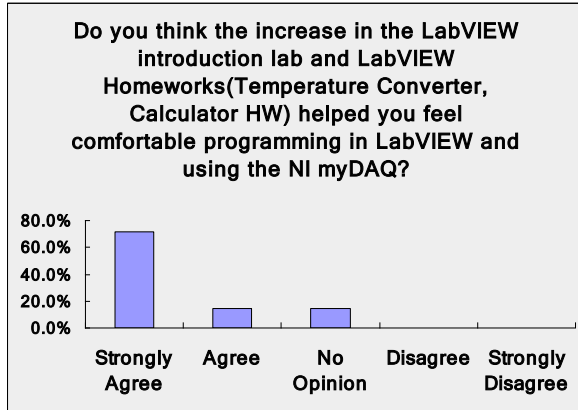


Figure 15: Spring 2011 Survey Result

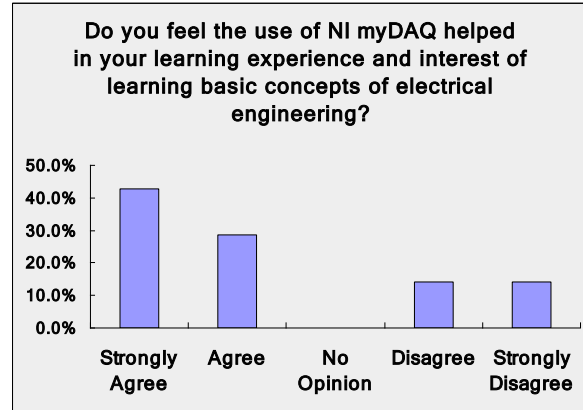


Figure 16: Spring 2011 Survey Result

## Future

We see a positive impact in providing students with tools that they can keep and use at any time. The ability to perform laboratory level experiments in the dorm room allows for increased pre-labs in order to cover more complex material during the supervised lab time. We have had a number of students do make up labs and bring in their completed circuit and lab report during TA office hours for demonstration and sign-off. Prior to implementation of the NI myDAQ, students would often take a zero on the lab, missing out on the lab experience and concepts.

At the entry level for courses, such as Introduction to Electrical and Computer Engineering, the intention of the lab is to become comfortable with lab equipment, reinforce concepts from the lecture, and develop an intuitive feel for the concepts taught in class by having real world experience with the theory being studied. A tool, such as NI myDAQ, allows us to increase the time engaging with experiments that further reinforce these three goals. In addition, the student working at home has to be more independent than with a TA present that they can easily and frequently ask for assistance. This independence and confidence with the lab equipment increases the likelihood that students will explore more on their own. We hope to extend these benefits to lecture courses without a formal lab session through homework problems that reinforce theory with hands-on experiments. We distribute a breadboard and small parts kits along with the NI myDAQ both for in-lab experiments and to facilitate further exploration at home. As the current freshman class matriculates through the program we hope to add NI myDAQ exercises to the sophomore year course work in circuit theory and linear systems. These exercises will allow students to gain first hand experience with the concepts they are learning, for instance exploring how varying capacitance value in a simple circuit effects pulse shape.

For the advanced circuits lab, EE 438 Electronic Circuits I, the junior year circuits course will also introduce new assignments to be performed with the NI myDAQ. For this lab, students simulate a circuit in LabVIEW and build and measure that same circuit with NI myDAQ. Students then simultaneously observe the physical circuit behavior with the simulated behavior. The program runs in real time allowing the student to adjust the model parameters in the program

so that the simulated and observed data match. Students can also adjust the physical circuit to match the simulation. Either approach allows the students to develop a more intuitive feel for how models work and how they relate to physical components.

Additional experiments demonstrate dispersion in a simple circuit. Starting with a simple circuit that has no dispersion, consisting of two resistors, a capacitor, and an inductor, students measure the terminal behavior. The terminal behavior looks like a resistor, even though there is internal energy storage. This measurement reinforces the concept that terminal behavior does not necessarily specify internal behavior. Students can then map the spectrum, which should be flat. However, since component values are not exact the spectrum will deviate from the expected flat spectrum. In this experiment, students gain first hand experience of how component tolerance effects circuit output.

Formalized labs have very specific times limits, which deters students from “playing around” with these effects. By integrating the NI myDAQ into the curriculum students can have significantly increased time to interact with physical circuits and gain an intuitive understanding of concepts through experience.

Current developments of homework assignments utilizing the NI myDAQ is being prepared to be used not only for the EE302 lecture but also future courses like advanced circuits lab, EE 438 and EE411 the Circuit Theory course. This is expected to change how the students view engineering education. It will not be a passive experience where students do what boundary is set by the professors and workout problems assuming ideal settings but actually get to explore on their own theoretical concepts and see and experience practical and real world results.

## **Conclusion**

In this paper a study of the adoption of a hands-on instrumentation into the Introduction to Electrical Engineering course for first year students is presented. With the limited amount of topics covered in the EE302 course, beginning engineering students are exposed to practical engineering techniques utilizing the NI myDAQ in the lab curriculum. Also because the NI myDAQ is a portable device the student’s practical learning experience that was once limited to the laboratory setting of school is now taken into the dorm rooms, backyards, living room and coffee shop that students engage learning actively.

Still the cost of purchasing the device is, from student’s point of view, set too high. But this is expected to decrease as the demand and adaptation of the device in the already growing universities around the world increases. Also without more exposure to labs utilizing the more advanced features of the NI myDAQ the students likeliness of continued utilization outside of the lab is marginal. Further studies of the NI myDAQ adaptation in advanced topics of engineering is needed and a trial of the labs with a comprehensive change of the prelabs and labs utilizing the NI myDAQ in a more creative way is necessary to justify the NI myDAQ as a device with the potential to improve the students engineering education experience, but the strength discussed of the NI myDAQ used as an educational tool and student feedback through surveys shows that the use of NI myDAQ is a promising tool to provide students with a new dimension to electrical engineering education.