Engaging Electrical and Computer Engineering Freshman Students with an Electrical Engineering Practicum

Dr. John Okyere Attia P.E., Prairie View A&M University

Dr. John Okyere Attia is Professor of the Electrical and Computer Engineering at Prairie View A&M University. He teaches graduate and undergraduate courses in Electrical and Computer Engineering in the field of Electronics, Circuit Analysis, Instrumentation Systems, and VLSI Design. Dr. Attia earned his Ph.D. in Electrical Engineering from University of Houston, an M.S. from University of Toronto and B.S. from Kwame Nkrumah University of Science and Technology, Ghana. Dr. Attia has over 75 publications including four engineering books. His research interests include innovative electronic circuit designs for radiation environment, radiation testing, and power electronics. Dr. Attia is the author of the CRC book, Electronics and Circuits Analysis Using MATLAB, 2nd Edition He has twice received outstanding Teaching Awards. In addition, he is a member of the following honor societies: Sigma Xi, Tau Beta Pi, Kappa Alpha Kappa and Eta Kappa Nu. Dr. Attia is a registered Professional Engineer in the State of Texas.

Dr. Lisa D. Hobson Ph.D., Prairie View A&M University

Dr. Lisa Hobson is Associate Professor of Educational Leadership at Prairie View A&M University and has served in the professorate since 1999. She holds a Ph. D. in Educational Administration from the University of Wisconsin-Madison with a minor in Curriculum and Instruction. Dr. Hobson has written and received grants on the k-12 and university levels related to the areas of teacher recruitment and retention, language arts, mathematics, science, and technology. Her research areas include: leadership and organizational development, teacher leadership, mentoring, student retention, and student engagement.

Pamela Holland Obiomon, Prairie View A&M University

Pamela Obiomon received a BS degree in electrical engineering from the University of Texas, Arlington TX, in 1991, a MS in engineering degree from Prairie View A&M University in 1993, and a PhD degree in electrical engineering from Texas A&M University in 2003. From 1998 to 1999, Dr. Obiomon served as an adjunct faculty at the Rochester Institute of Technology, in the Department of Micro-electronics in Rochester, New York. From 2000-2002, she was the lead data processing system hardware engineer in the Shuttle Avionics Integration Laboratory at the Johnson Space Center in Houston, TX. In 2003, she joined the Department of Electrical and Computer Engineering at Prairie View A&M University. She is currently serving as the Department Head of the Electrical and Computer Engineering Department at Prairie View. Dr. Obiomon's research interests include the development of integrated microsystems powered by energy scavenging for biomedical and environmental devices and radiation effects on devices.

Mr. Mahamadou Tembely, Prairie View A&M University

Mahamadou Tembely is a Ph.D student at Prairie View A&M University, Texas. He received the 2014 Outstanding MS Graduated Student award for the department of electrical and computer engineering. He is the author of several papers.

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ABSTRACT:

A large percentage of students in engineering programs switch their majors in the first two years. Some of statistics are due to teaching approaches that are not suitable for current populations of students that learn and acquire new knowledge quite differently from those of earlier generations. Several new pedagogical paradigms have been proposed to improve engineering education, such as the use of "hands-on" tools to change the learning style in the engineering classroom to more engaging teaching pedagogies. An approach that is being used to engage and inspire the electrical and computer engineering freshman students is the Electrical Engineering Practicum. In this paper, the researchers discuss the various laboratory experiments performed by the students, the knowledge and skill learnt by the students, the lessons learned while introducing Analog Discovery board into the freshman curriculum. Survey results indicate that students are benefiting from the use of the (ADB). A high percentage of students indicated that the use of the (ADB) was suited to their learning needs, and that the (ADB) motivated them to learn the course content. In addition, the students' base knowledge increased as the result of use of the (ADB). Furthermore, through the integration of the Electrical Engineering Practicum and the (ADB), the students developed interest in the course, developed skills in working collaboratively with fellow students, developed confidence in the content area. Moreover, the students developed attitudes of self-direction and self-responsibility.

1 INTRODUCTION

It has been reported that a large percentage of students in engineering programs switch their majors in the first two years. A study has reported that retention rates can be improved through multiple strategies that include making curriculum changes, moving practical engineering laboratories earlier in the curriculum, integrating projects into classes, and other class enhancements[1]. Another reason given by students who switch to other majors is that teaching approaches are not suitable for current populations of students who learn and acquire new knowledge quite differently from those of earlier generations[2, 3].

Several new pedagogical approaches have been proposed to improve engineering education, such as the use of *hands-on* tools to change the learning style in the engineering classroom to more engaging teaching pedagogies. Hands-on learning has proven to be an effective approach for improving retention by making learning experiences more motivating for students[4, 5, 6]. The benefits of portable hands-on learning equipment include improved student engagement[7, 8, 9], and improved student learning[10].

Several portable hands-on learning equipment are available, such as Analog Discovery[11], MyDaq[12], Lab-in-a-Box[13, 14], Tessal[15], and mobile studio [9]. The Electrical Engineering Practicum has been used to improve retention in an institution[7], and this work will not address the use of the Practicum for increasing retention at a Historically Black University. This paper presents the results associated with the impact of the integration of hand-held mobile technology, the Analog Discovery board, on student learning in freshman class of electrical and computer engineering students. The paper describes the hands-on learning experiences of freshman students who used the Electrical Engineering Practicum. In addition, this paper discusses the various laboratory experiments performed by the students, the knowledge and skill learnt by the students, the lessons learned while introducing Analog Discovery Board (ADB) into a freshman course.

2 THE ELECTRICAL ENGINEERING PRACTICUM

The Analog Discovery Board was developed by Digilent in conjunction with Analog Devices, Inc. The Analog Discovery board communicates to a computer through USB interface. The operating software, WaveForms, provides virtual instrument functions. The virtual instruments include two channel voltmeter, two channel oscilloscope, two channel waveform generator, 16 channel logic analyzer, and 2 fixed (+/- 5 V) dc power supplies, network analyzer and spectrum analyzer[11]. Figure 1 shows the main window of the WaveForms software. The virtual instruments are equivalent to more expensive desktop instruments when the board is connected to a laptop computer through its USB port. The Analog Discovery board is low-cost and portable (about the size of playing cards).

Figure 1: Main Window of WaveForms Software showing the Virtual Instruments

The Electrical Engineering Practicum is a cloud-based book[16] with experiments that use the Analog Discovery Board and electronic parts kit to facilitate hands-on learning and self-exploration by the students. All the experiments in the Electrical Engineering Practicum book use the Analog Discovery board for signal generation, display and measurements. The Analog Discovery Board enables students to quickly test real-world functional circuits anywhere and anytime with their own personal computers. The Analog Discovery module has proven to be effective in motivating engineering students to study foundation courses[7].

3 LABORATORY LEARNING EXPERIENCES

ELEG 1021 Introduction to Electrical and Computer Engineering Laboratory is a first year course at Prairie View A&M University. In the course ELEG 1021, the first year students perform twelve experiments from the Electrical Engineering Practicum book[16]. The laboratory experiments that were performed in the ELEG 1021 course are shown in Table 1. A few of the experiments will be described in this section.

Table 1: Laboratory Experiments Performed in ELEG 1021 Class

Number	LABORATORY TOPICS
1	Introduction to Electrical Engineering, Lab Instruments, Procedures, Personal Test Lab
2	Power Supplies and Electrical Power
3	Signal Generators and Waveforms
4	Resistors and Ohm's Law
5	Diodes and Rectification
6	Capacitors and Time Constants
7	Inductors and Resonance
8	Thermal Sensors and Temperature
9	Accelerometers and Tilt Sensing
10	Microphones and Sound Sensing
11	Radio Frequencies and Amplitude Modulation
12	Amplifiers and Sound Amplification

(i) Resistive-LED Circuit:
An experiment the students performed is shown in Figure 2. The students built a resistive-LED circuit on a breadboard. The voltage source of the circuit is the Arbitrary Waveform Generator of the Analog Discovery board. The voltmeters of the Analog Discovery board were used to measure the voltage across resistor R1 and the LED. The students used Ohm’s Law to calculate the current flowing through the LED. The LED was changed to green and yellow to allow the students to determine the conducting voltages of various colored LEDs.

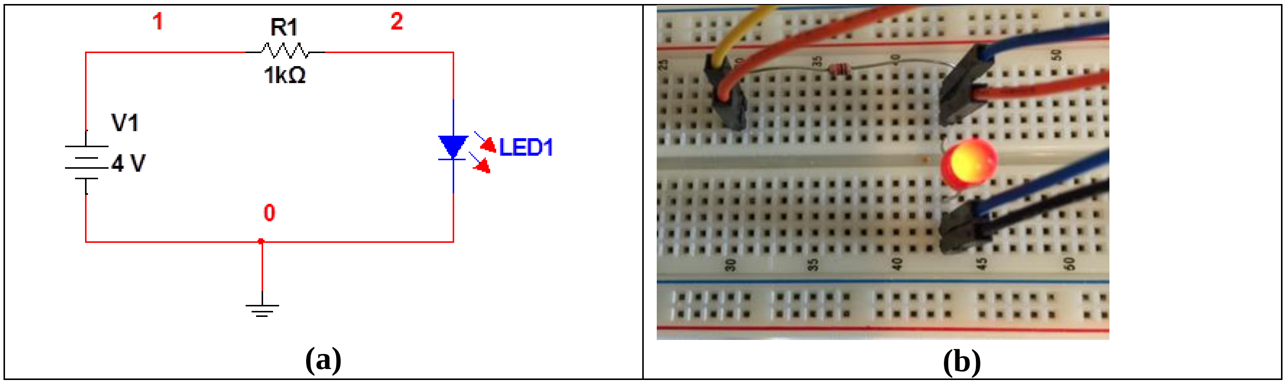

Figure 2: (a) Resistive-LED Circuit, (b) Prototype of the Resistive Circuit

(ii) <u>Time-varying Signals and LEDs</u>

The students performed an experiment on a circuit with LEDs, which is shown in Figure 3. If the input voltage is a DC, only one of the LEDs turns on. However, if a sinusoidal or a square waveform is used as the input, the LEDs will alternately turn on and off. This experiment is useful in allowing the students to learn the differences between direct current and alternating current signals.

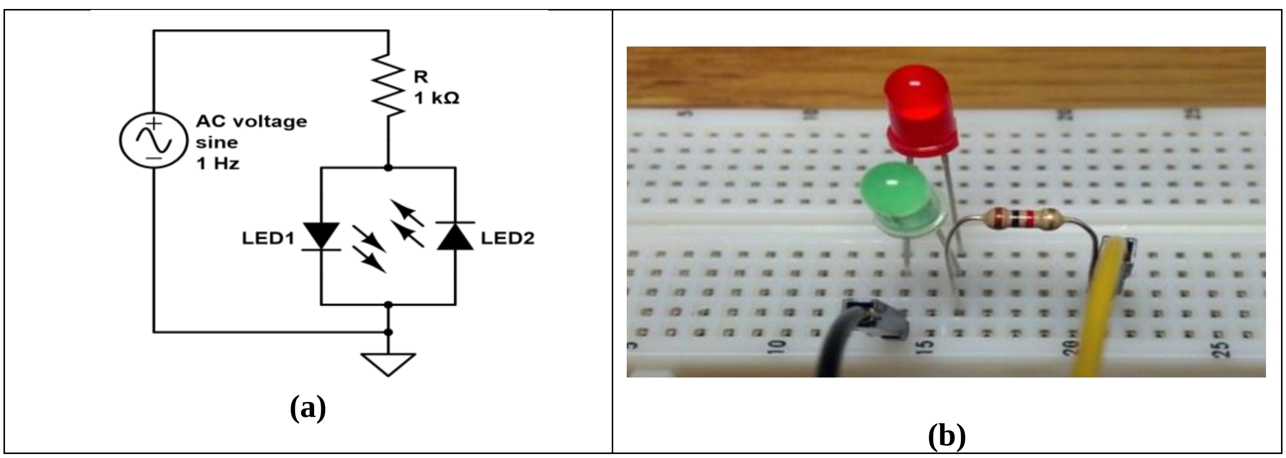

Figure 3: (a) AC Voltage Circuit with LEDs, (b) Prototype of the AC Voltage Circuit [16]

(iii) <u>Voltage Division</u>

A voltage divider experiment the students completed is shown in Figure 4. The students built a resistive circuit on a breadboard. The voltage source of the circuit is the Arbitrary Waveform Generator of the Analog Discovery board. The voltmeters of the Analog Discovery board were used to measure the voltage across the voltage source and resistor R2. The scope channel 1 measured the voltage of the power supply (nodes 1 and 0), and the scope channel 2 the voltage across R2 (nodes 2 and 0). The voltmeter readings are shown in Figure 4(b). Using voltage divider rule, the voltage across the resistor R2 is calculated as:

$$V2 = \frac{(100K) * (5V)}{120K} = 4.16\, V$$

The measured value was 4.088 V, which is about 1.7 percent deviation from the calculated value. The students were asked to reflect on the differences between the measured voltage and the calculated one, and to give reasons for the discrepancy between the measured and calculated voltage. The measurements made by the students allowed them to have a deeper understanding of the Voltage divider rule.

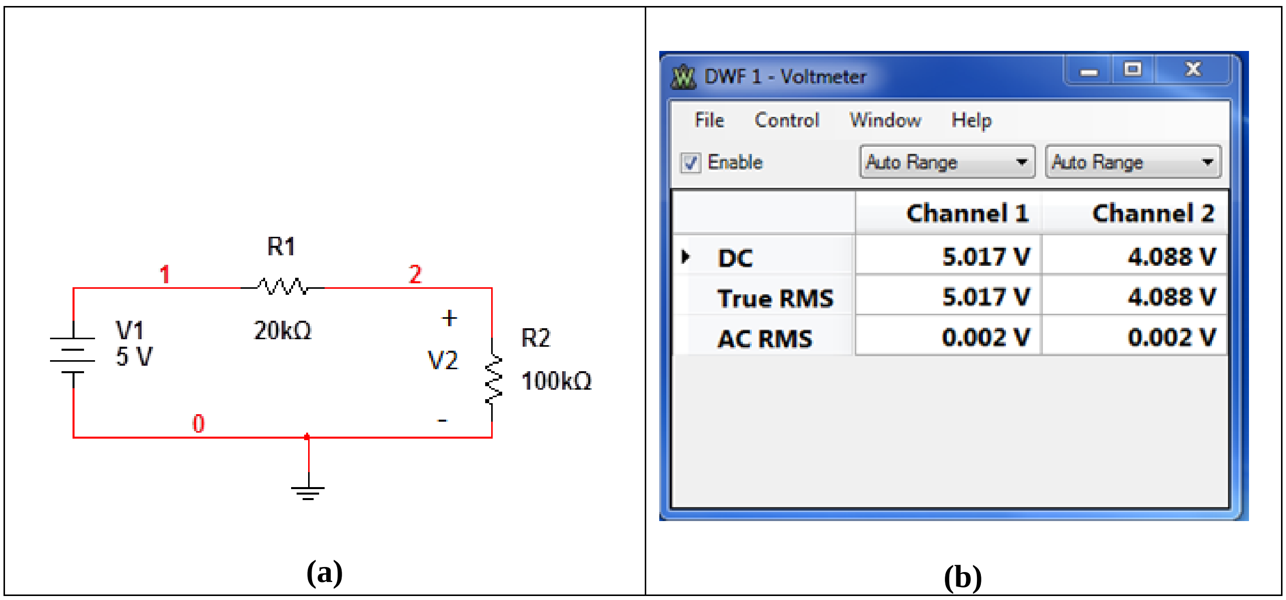

Figure 4: (a) Resistive Circuit (b) Voltmeter Readings of the Voltage of the Power Supply (Channel 1) and Voltage across R2 (Channel 2)

(iv) <u>Measurement of RC Time Constant</u>

Figure 5 is the circuit for measuring time constant. The capacitor is connected to channel 1 of the scope of the Analog Discovery board, and the input square wave signal is generated from the Arbitrary Waveform Generator, AWG1. The time constant was measured by using the display of the scope. The measured time constant was compared with the calculated time constant, RC. The students were also asked to explain any differences between the measured and calculated time constant.

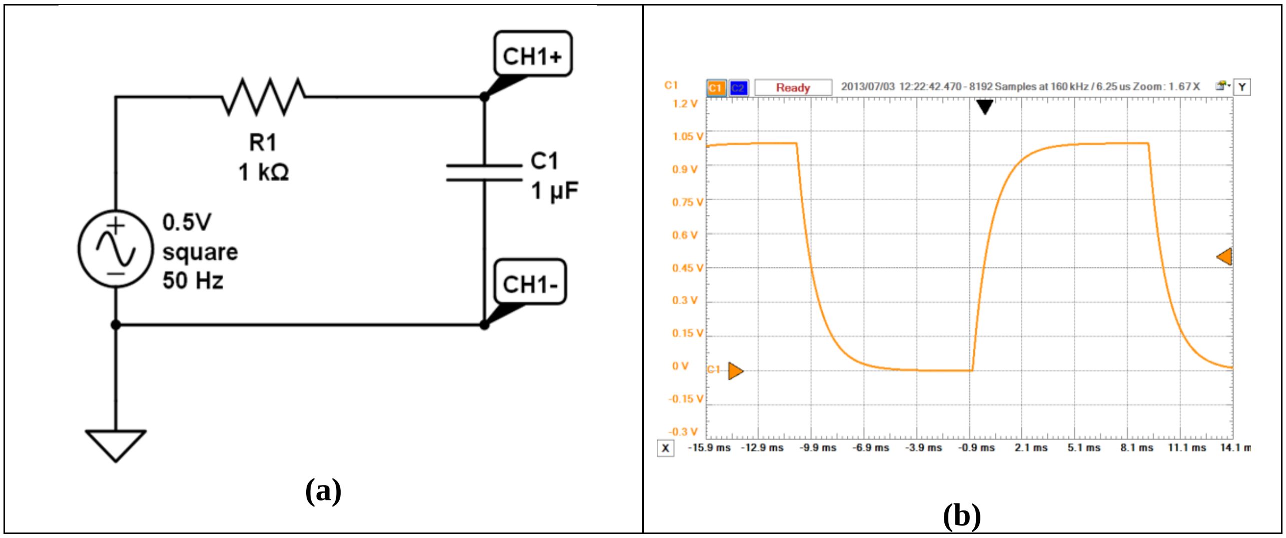

Figure 5: (a) RC Circuit, (b) Scope Display of the Voltage across Capacitor C1 [16]

(v) Resonant Circuit and Bode Plot

A RLC resonant circuit, shown in Figure 6, was built. The students used the Network Analyzer of the ADBto obtain the magnitude and phase characteristics of the RLC resonant circuit. Figure 6 shows the Bode plot obtained from an RLC circuit through the use of the Network Analyzer.

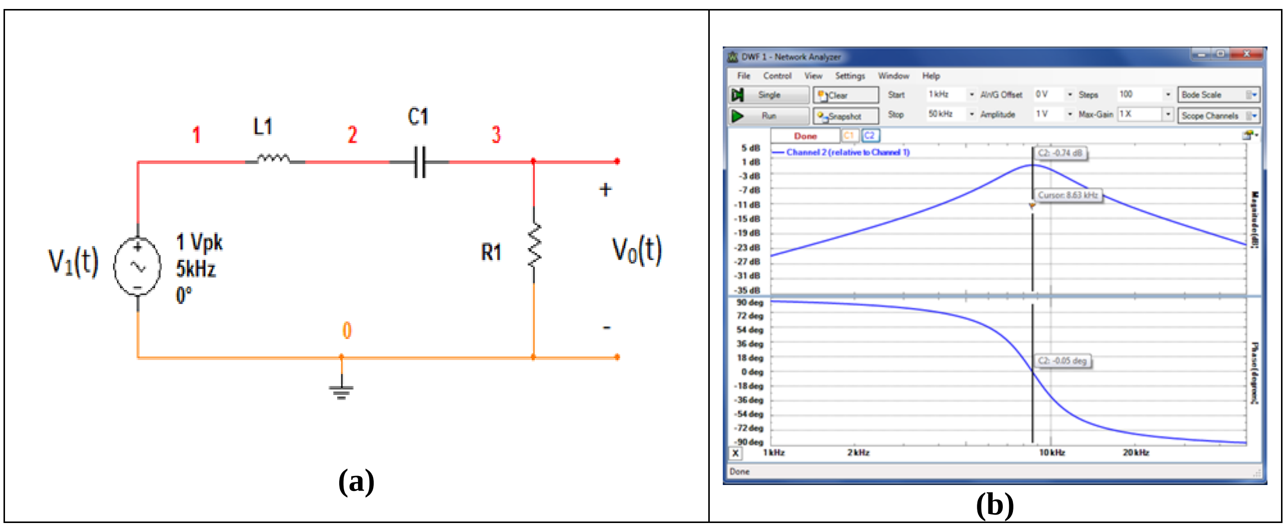

Figure 6: (a) RLC Resonant Circuit (R1 = 1 KΩ, L1 = 40 mH, and C1 = 0.01 µF), (b) Magnitude and Phase Response of the RLC Circuit

(vi) Microphone and Sound Sensing

Another experiment performed by the students is sound sensing. The setup is shown in Figure 7. The speaker for the experiment was the electronic device GT0950RP3 and the microphone was ADMP504. The signals that powered the speaker and microphone came from the Arbitrary Waveform Generators of the Analog Discovery board. The sound from the speaker received by the microphone was displayed on the scope of the Analog Discovery board. The students experimented with the effects of changes in the frequency of the sine wave of the Arbitrary Waveform Generator that powers the speaker with regard to the voltage displayed on the scope. In addition, the loudness of the speaker with respect to the amplitude of the input sine wave was explored by the students.

(vii) Non-inverting Amplifier
The students were asked to build a non-inverting amplifier with operational amplifier OP484EP, shown in Figure 8. Several virtual instruments were used for this experiment. The Arbitrary Waveform Generator AWG1 was used to generate the sinusoidal source voltage. The two dc power supplies (+5 V and -5 V) were used to energize the operational amplifier, the scope was used to measure input and output signals of the amplifier. From the measurements made by the scope, the gain was calculated. The theoretically-calculated gain of the non-inverting amplifier was compared with the measured gain of the amplifier.

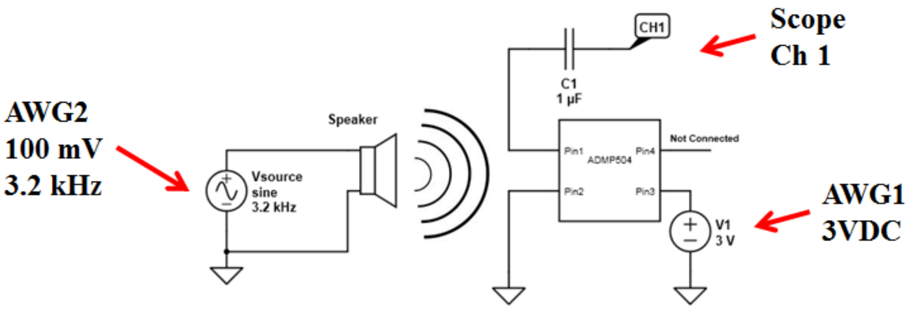

Figure 7: Microphone and Sound Sensing [16]

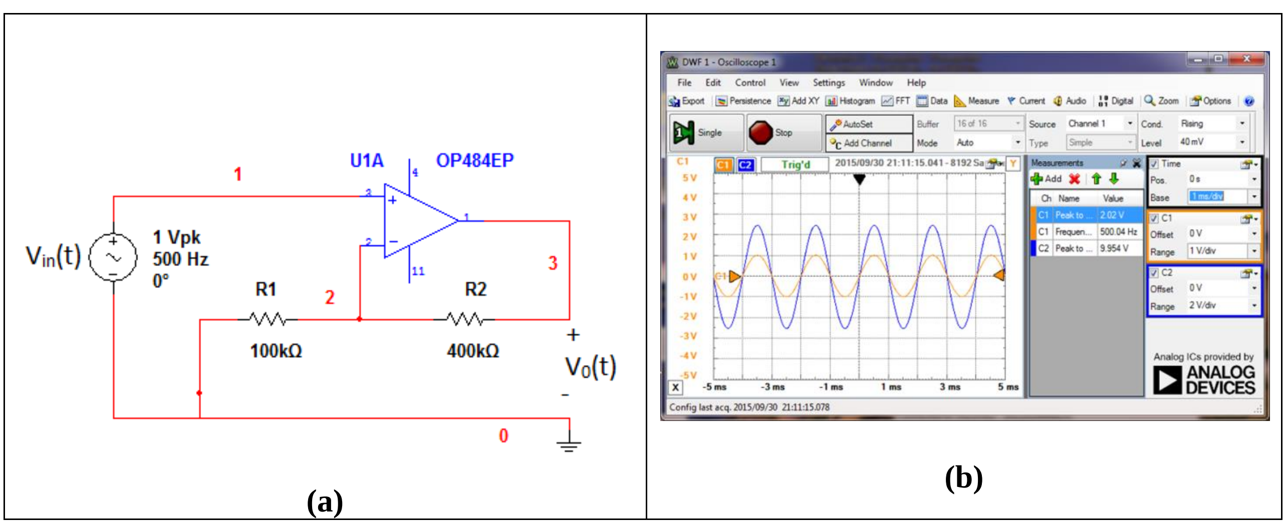

Figure 8: (a) Non-inverting Amplifier built using OP484EP Op Amp, (b) Display of Input and Output Sinusoidal Waveforms of the Non-inverting Amplifier

4 KNOWLEDGE AND SKILLS LEARNT BY STUDENTS

ELEG 102:1 Introduction to Electrical and Computer Engineering Laboratory is a first laboratory-oriented course for electrical and computer engineering students at Prairie View A&M University. The ELEG 1021 course introduces basic laboratory skills to the students, and also allows the students to explore and experiment in the areas of (i) circuit analysis, and (ii) electronics. The topics explored by the students will be studied in more detail by the students latter on in their curricula (sophomore and junior years). With regard to basic circuit analysis, the students learnt: (i) Ohm's Law, (ii) voltage divider rule, (iii) current divider rule, (iv) charging and discharge of a capacitor of RC circuit, (v) resonant RLC circuit.

In the ELEG 1021 course, students are introduced to basic electronics devices and circuits such as: (i) semiconductor diodes and LEDs, (ii) half-wave rectification, (iii) Op Amp inverting and non-inverting amplifiers, (iv) envelope detection circuit. In addition, the students also experimented with electronic sensors such as: (i) TMP01 Thermal Sensor, (ii) ADXL237 Accelerometer, (iii) GT0950RP3 Speaker and ADMP504 Microphone.

With regard to the laboratory skills mastered in the class, the students are able to: (i) read resistor values by using resistor color code, (ii) build electrical and electronic circuits by using breadboard, (iii) use virtual instruments, such as arbitrary waveform generator, scope, power supply, voltmeter, network analyzer, and (iv) obtain Bode plots with Network Analyzer.

5 LESSONS LEARNED AND RECOMMENDATIONS FOR OTHER INSTITUTIONS

During the first time the ELEG 1021 course was taught with the Electrical Engineering Practicum and ADB, the students did not appreciate the power and capabilities of the low cost portable equipment, the ADB. The students were not aware of the existence of desktop laboratory equipment, such bench scopes, power supplies, signal generators, voltmeters and Network Analyzers. During the subsequent course offerings of ELEG 1021, the students were sent to an electronic laboratory to be introduced to desktop laboratory equipment in the laboratory. The students appreciated how small portable equipment can perform functions similar to those of several desktop equipment that cost several thousands of dollars. It is beneficial to students if they are shown bench-top instruments during the first class for them to appreciate the capabilities of the ADB.

Since the first year students in the ELEG 1021 course are learning bread-boarding, troubleshooting, basic electronics and circuit analysis, it is important to make the class as small as possible to provide adequate attention to the students in the laboratory. When the class size was very large during on semester, the post-survey results were poor. If the class is large, several laboratory assistants, skilled with the use of ADB, are strongly recommended.

The Electrical Engineering Practicum book has sixteen experiments that may be completed during one semester. The first six experiments are relatively easy to perform and they are less time-consuming. However, the latter experiments are long and take considerable amount of time to complete. In the ELEG 1021 course, twelve of the sixteen experiments are completed during a semester. Two weeks are scheduled for mid-semester and final examinations. Another week is devoted to discussion of engineering ethics and an ethics quiz. Institutions may have to make a thoughtful decision with regard to experiments their students may perform during a semester or a term.

6 ASSESSMENT RESULTS

The students who took the ELEG 1021 course completed surveys. The survey results are available for the following semesters: (i) spring 2015, (ii) fall 2015, and (iii) spring 2016. 13 students completed the survey during the spring 2015 semester, 43 students in the fall 2015 semester and 18 students in spring 2016 semester. Table 2 shows the survey results for the three above mentioned semesters for the use of the Electrical Engineering Practicum in the freshman course.

Table 2 Perceived Changes with the Use of Analog Discovery Board in the Course

#	Perceived Changes	%*
1	Use was relevant to my academic area	81
2	My knowledge has increased as a result of Use	84
3	Use of ADB motivated me to learn the content	81
4	Use of ADB suited my learning needs	89
5	The time allotted for portable hands-on hardware was adequate	82

***** Number represents percentage of participants who responded, “strongly Agree”/ “Agree” in post-survey, n=74

From Table 2, a high percentage of students indicated that the use of the ADB was suited to their learning needs (89%), and that the ADB motivated them to learn the course content (81%). In addition, it is interesting to note that the knowledge of the students increased as the result of use of the ADB (84%). Furthermore, the students perceived that the use of the portable hands-on hardware was relevant to their academic area (81%). Moreover, the ELEG 1021 class is scheduled for two hours per week. From the survey results, it seems that the time allotted for use of the portable hands-on hardware is adequate (82%). Similar results have been obtained by thirteen institutions who used the ADB in a collaborative project[17, 18].

Table 3 shows the effects of integration of the ADB and Electrical Engineering Practicum on the students in the freshman course. Through the integration of the Electrical Engineering Practicum and the ADB, the students developed interest in the course (80%), developed skills in working collaboratively with fellow students (80%) and developed confidence in the content area (81%). Furthermore, the Electrical Engineering Practicum course helped students to recall course content (75%). It should be noted that a high percentage of students were confident to complete lab assignments (79%). Moreover, it is interesting to note that the students developed attitudes of self-direction and self-responsibility (84%). This might be due to the ADB being more suited to their learning needs, being motivated to learn, and their increase in knowledge as the result of use of the ADB in the course.

Table 3 Effects of Integration of Analog Discovery Board and Electrical Engineering Practicum in the Freshman Course

#	**Perceived Changes**	**%***
1	Develop confidence in content area	81
2	Recall course content	75
3	Develop interest in content area	80
4	Worked collaboratively with fellow students	80
5	Develop attitudes in self-direction and self-responsibility	84
6	Confidently complete lab assignments	79

***** Number represents percentage of participants who responded, "strongly Agree"/ "Agree" in post-survey, n=74

7 CONCLUSIONS

The hand-held mobile technology, ADB, is being used to engage freshman electrical and computer engineering students. The mobile technology and the Electrical Engineering Practicum allowed the students to learn basic laboratory skills. In addition, the students were introduced to basic circuit analysis tools, and they performed experiments with electronic devices and electronic circuits. Survey results indicate that students are benefiting from the use of the ADBs . A high percentage of students indicated that the use of the ADB was suited to their learning needs, and that the ADB motivated them to learn the course content. In addition, the knowledge of the students increased as the result of use of the ADB. Through the integration of the Electrical Engineering Practicum and the ADB, the students developed interest in the course, developed skills in working collaboratively with fellow students and developed confidence in the content area. Moreover, the students developed attitudes of self-direction and self-responsibility.

ACKNOWLEDGEMENT

This work is supported by the National Science Foundation under NSF Award Number 1255441 for Experimental Centric Based Engineering Curriculum for HBCUs.

REFERENCES

1. ASEE Student Retention Project, "Going the Distance: Best Practices and Strategies for Retaining Engineering, Engineering Technology and Computing Students," ASEE, 2012.
2. Ohland, M.W., S.D. Sheppard, G. Lictenstein, O. Eris, D. Chachra, and R. A. Layton, "Persistence, engagement, and migration in engineering programs," Journal of Engineering Education, vol. 97, pp. 259-278, 2008.
3. Ohland, M.W., C.E. Brawner, M.M. Camacho, R. A. Layton, R. A. Long, S.M. Lord, and M. H. Wasburn, "Race, Gender, and Measures of Success in Engineeering Education," Journal of Engineering Education, Vol. 100, pp. 225 – 252, April 2011.

4. Byers, L. K., J. W. Kile, C. Kiassat, "Impact of hands-on first year course on student knowledge of and interest in engineering disciplines," Proceedings of ASEE Annual Conference and Exposition, Indianapolis, IN, June 2014.
5. Connor, K. A., B. Ferri, and K. Meehan, "Models of Mobile Hands-On STEM Education," Proceedings of ASEE Annual Conference and Exposition, Atlanta, GA, June 2013.
6. Huette, L. (2011, June), *Connecting Theory and Practice: Laboratory-based Explorations of the NAE Grand Challenges* Paper presented at 2011 Annual Conference & Exposition, Vancouver, BC. https://peer.asee.org/17655, June 2011.
7. Bowman, Robert , "Inspiring Electrical Engineering Students Through Fully-Engaged Hands-on Learning," 2013 IEEE 56th International Midwest Symposium on Circuits and Systems, pp. 574 – 577, 2013.
8. Ochoa, H. A. and M. Shirvaikar, "The Engagement and Retention of Electrical Engineering Students with a First Semester Freshman Experience Course," ASEE Annual Conference and Exposition, Vancouver, Canada, June 2011.
9. Millard, John," Workshop – Improving Student Engagement and Intuition with the Mobile Studio Pedagogy," Proceedings of the 38th ASEE/IEEE Frontiers in Education Conference, pp. W3C-1, October 22 – 25, 2008.
10. Radu, Mihaela, "Developing Hands-on Experiments to Improve Student Learning via Activities Outside the Classroom in Engineering Technology Programs, " 4th IEEE Integrated STEM Education Conference, March 8, 2014.
11. Analog Discovery board, Information on the Analog Discovery board and supporting material are available at http://www.digilentinc.com/Products/Detail.cfm?NavPath=2,842,1018&Prod=ANALOG-DISCOVERY, Viewed, January 12, 2016
12. MyDAQ, Who is using myDAQ? http://www.ni.com/white-paper/11465/en
13. Hendricks, R.W., K-M. Lai, and J.B. Webb, "Lab-in-a-Box: Experiments in Electronic Circuits That Support Introductory Courses for Electrical and Computer Engineers." Proc. ASEE Annual Meeting, June 12–15, 2005, Portland OR.
14. Henricks, R.W. and K. Meehan, "Lab-in-a-Box: Introductory Experiments in Electric Circuits," 3rd Edition, Hoboken, NJ, John Wiley and Sons, 2009.
15. Ferri, B., J. Auerbach, J. Michaels, and D, Williams, "TESSAL: A Program for Incorporating Experiments into Lecture-Based Courses within the ECE Curriculum," ASEE Annual Conference and Exposition, Vancouver, Canada, June 2011.
16. Bowman, Robert, *Electrical Engineering Practicum*, Online Textbook, Trunity.com, 2014.
17. Connor, K.A., D. Newman, K. Gullie, Y. Astatke, C. J. Kim, J. Attia, P. Andrei , . M. Ndoye, "The Implementation of Experimental Centric Pedagogy in 13 ECE Programs - The View from Students and Instructors, " Proc. of ASEE 123rd Annual Conference & Exposition, New Orleans, LA, June 26-29, 2016.
18. Connor, K.A., Y. Astatke, C. J. Kim , M.F. Chouikha, D. Newman, K. Gullie, A.A. Eldek, S. S. Devgan, A.R. Osareh, J. Attia, S. Zein-Sabatto, and D. L. Geddis, "Experimental Centric Pedagogy in Circuits and Electronics Courses at 13 Universities," Proc. of ASEE 123rd Annual Conference & Exposition, New Orleans, LA, June 26-29, 2016.