rhBNN+ Comprehensive Detections and Analyses of the Human Body Temperatures and Sounds by the Same Smart Mask.

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***Abstract*- This paper presents an active learning experience using a set of experiments for electrical and computer engineering technology students covering courses from the lower to the upper level division in the areas of electrical circuits and digital electronics. The experiments and associated tutorials are designed to help students with different backgrounds and skills to become proficient using laboratory equipment and to achieve a higher level of learning. By giving students more opportunities to improve their employability skills, they will be better prepared to enter the competitive work force and to compete with graduates from other universities. The experiments are developed around portable computer-based-test –equipment, the Analog Discovery platforms. The platforms enable students to quickly and easily build and test real-world functional circuits anytime, using their own computers and associated free computer-based-tools. Results, including assessment data, lessons learned and challenges, conclude the paper.**

***Index Terms*—active learning, circuits, debugging, experiments.**

I. INTRODUCTION

The publication *"The Engineer of 2020: Visions of Engineering in the New Century",* by The National Academy of Engineering (NAE) Committee on Engineering Education (CEE) aims to identify the opportunities and challenges for the 21st century, anticipating and shaping the future practice of engineering, the characteristics of the engineering workforce and their education. Engineering schools should attract the best and brightest students and be open to new teaching and training approaches [1].

According to published reports, there is strong evidence that the top priorities in terms of future skills will be: (i) practical applications, (ii) theoretical understanding and (ii) creativity and innovation [1], [2], [3]. The student population of today is different than 10-15 years ago**.** Educators must make adjustments in their delivery strategies to engage the students of the new millennium.

Variance in learning styles requires different pedagogical approaches. By providing the students with more opportunities for "hands-on" experience, a more effective instruction can be provided. According to Kolb's Experiential Learning Model, there are four types of learners: Type 1 (concrete, reflective) - the diverger; Type 2 (abstract, reflective) - the assimilator; Type 3 (abstract, active) - the converger; Type 4 (concrete, active) - the accommodator. Traditional science and engineering instruction focuses almost exclusively on lecturing, a style comfortable for only Type 2 learners. Effective instruction involves teaching all learning styles: motivating each new topic (Type 1), presenting the information and the methods associated with the topic (Type 2), providing opportunities for practicing the method (Type 3), and encouraging exploration of applications (Type 4) [4].

Universities invest greatly in many technologies and equipment, but because they are often too expensive and complex for use outside of the laboratory, the majority of engineering programs provide only limited access to these technologies and equipment in the form of two or three hour weekly lab sessions. During these short sessions, students, usually working in team of two, must apply concepts learned in lectures, use complex laboratory equipment to build experiments, debug and test circuits, record and analyze data, and write lab reports. Sometimes, slower student teams struggle to finish the activities in the allotted time and often wind up missing the main points in an effort to complete the detailed steps for the project. While working in a team is an important skill, each student also needs individual practice setting up the lab equipment, measuring, recording data, and troubleshooting in order to reach his or her full potential as a technical professional [5].

Engineering education has to develop novel approaches to reach and motivate a more diverse student population, in order to overcome the limitations and challenges presented above. New educational approaches are possible due to the continued revolution in electronic miniaturization which makes possible portable, low-cost computer-based test equipment that allows for valuable "hands-on" experiences for students anywhere and anytime. According to references [6] and [7], students retain 10% of what they read, but retain as much as 90% of what they say as they do something.

The Analog Discovery™ and recently Analog Discovery2 platform, manufactured by DiligentInc., are perfect examples of portable, low-cost computer-based test equipment, enabling students to experiment with advanced technologies and to build and test real-world functional circuits [6].

This paper presents an active learning experience using a set of experiments for electrical and computer engineering technology students covering courses from the lower to the upper level division in the areas of electrical circuits and digital electronics at Farmingdale State College, State University of New York. The experiments and associated tutorials are designed to help students to become proficient using laboratory equipment and to achieve a higher level of learning, allowing them to work outside the traditional classroom and lab settings. The experiments are designed to help students to develop essential employability skills and meet certain general education learning outcomes, such as : (i) apply knowledge of mathematics, science, and engineering, (ii) design and conduct experiments, as well as analyze and interpret data; (iii) ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

The remainder of this paper is organized in the following sections: Similar Pedagogies; Characteristics of Student Population at Farmingdale State College; Description of the Courses and Laboratory Experiments using the Analog Discovery Platform; Results; Conclusions.

II. Similar Pedagogies

Current models for "hands-on" education in engineering include a large variety of pedagogies, from in-class demos and labs, to labs done at home, "hands-on" homework, etc. According to [5] and [8], about two decades ago professor Don Millard from Rensselaer Polytechnic Institute started thinking about a way to enable students to perform experiments whenever and wherever they desire — experiments that use an oscilloscope, function generator, digital control and some form of power supply. The result was the Mobile Studio Project, a technology-based-pedagogy based on inexpensive hardware/software which, when connected to a PC, provides functionality similar to that of laboratory equipment (oscilloscope, function generator, power supplies). Building on the original Mobile Studio project, several universities develop similar projects and networks, such as [5]:

-*Lab-In-A-Box* (Virginia Tech); Students do all labs outside of class, with help from extensive tutorials and other online materials. It uses Analog Discovery platform.

-*TESSAL Teaching Enhancement via Small-Scale Affordable Labs* (Georgia Tech); Hands-on activities are integrated into lecture courses using myDAQ platform.

-*Center for Mobile Hands-On STEM* (Rensellear Polytechnic Institute, Georgia Tech, Virginia Tech, Rose-Hulman, Howard University, Morgan State University); It is currently a combined effort of TESSAL, Lab-In-A-Box and Mobile Studio groups.

-*HBCU Experiment-Centric Pedagogy* (Howard University, Alabama A&M University, Florida A&M University, Hampton University, Jackson State University, Morgan State University, Norfolk State University, North Carolina A&T State University, Prairie View A&M University, Southern University, Tennessee State University, Tuskegee University, and University of Maryland Eastern Shore); This project creates a sustainable Network of engineering faculty at Historically Black Colleges and Universities to focus on the development, implementation, and expansion of an experiment-centric instructional pedagogy, based on the Mobile Studio and other similar platforms like Analog Discovery.

References [9-17] present in detail the Mobile Studio and associated pedagogies (Lab-In-A-Box, TESSAL), from implementation strategies at different institutions and different course levels to assessment, lessons learned, successes and challenges.

References [18] and [19] present projects from the HBCU Experiment-Centric Pedagogy. Reference [18] presents the Infinity Project kit in a freshman course at Prairie View A&M University. The paper discusses strengths and limitations of the tools and includes assessment results indicating students' satisfaction with the entire project. Reference [19] presents instructors' efforts at Tuskegee University to create an environment for students that is conductive to innovation and creative thinking through curricular enhancement in Introductory Circuit Analysis courses using the Analog Discovery platform.

Instructors at other institutions, non-affiliated with the above mentioned projects, introduced similar pedagogies in their courses. Reference [20] presents instructional demos, in class-projects and hands-on homework in freshman and sophomore courses in Electrical Engineering at The Citadel, The Military College of South Carolina. It uses the Analog Discovery platform and web-based tutorials provided by DigilentInc. Reference [21] presents an effective utilization of the Analog Discovery board in upper division Electrical Engineering courses at Milwaukee School of Engineering. It discusses the suitability of the board for upper level courses and lessons learned. References [22] and [23] present University of Massachusetts Lowell own version of the "Laboratory in the Box" built around the Analog Discovery platform. It allows students to work on their labs on their own term, and access to tools to innovate and create on their own. The conclusion of the study is that the "*Laboratory in the Box concept is disruptive in terms of changing the accessibility of engineering students to state of the art test equipment*".

The majority of the pedagogies related to mobile "hands-on" education focusses on electrical and computer engineering programs, only few addressing engineering technology programs, to the best knowledge of the authors of this paper. Reference [24] presents a basic remote experiment for an introductory Electrical Circuits course for students enrolled at Savannah State University, Engineering Technology program. The authors of the study conclude that the variety of the hands-on laboratory exercises using the Analog Discovery platform helps students realize the impact of math and science in the Electronics Engineering Technology environment, and their intrinsic relationships to each other.

III. Characteristics of Student Population at Farmingdale State College

The experiments and associated tutorials that are presented in the next section of this paper were designed for students enrolled in the Electrical and Computer Engineering Technology programs at Farmingdale State College, State University of New York. They were designed considering the characteristics of the student populations enrolled at Farmingdale State College (FSC). Over 90 % of FSC students are commuting on daily basis from the greater New York metropolitan area and they hold full time jobs. Around 35% are first-generation college students (e.g., neither parent has earned a 4- year degree), and 30% are minority. The student population includes large numbers of "New Americans" (i.e., they or their parents were born outside of the US), coming from extremely diverse educational and cultural backgrounds. Many students have considerable financial need (with 30% receiving Pell grants) [25]. Distinctive characteristics and special needs of the "new normal" students who attend Farmingdale State College (and most American institutions) are presented in detail in reference [25].

The Department of Electrical and Computer Engineering Technology, School of Engineering Technology, plays an important educational role in the region, attracting a large number of transfer students from the community colleges located in New York metropolitan area and region. Approximately 50 % of the sophomore and junior classes in the Electrical Engineering Technology (EET) and Computer Engineering Technology (CET) programs are transfer students from community colleges. Students enrolled in these programs have a large range of skills and aptitudes, in terms of math, sciences, and experience with laboratory test equipment, computer-based-tools, and programming. Retention rate is also an issue, especially at the freshman level. One of the conclusion of the study regarding student population at FSC is: "*to educate today's new undergraduate student effectively, one needs to engage students in active, experiential learning*", which is the main focus of the pedagogy presented in this paper.

Graduates of the four year technology engineering programs enter positions most likely in sectors such as construction, manufacturing, product design, testing, technical services, sales, according to ABET [26]. Specific careers in testing and product engineering require excellent debugging skills, mastery of test equipment and computer-based-tools to develop test plans and procedures. During a recent meeting with the Industrial Advisory Board of the department, one of the board member mentioned the lack of debugging skills among graduates, strongly recommending to reinforce these skills very early in the curriculum (June 2017).

IV. Description of Experiments Using the Analog Discovery Board

The experiments and associated tutorials presented in this paper were designed using the Analog Discovery platform, powered by a Hi-Speed USB port and free Waveform software. Fig. 1 presents the platform. The experiments can be updated to Analog Discovery2 platform and Waveform 2015 software. Reference [27] presents detailed information about the capabilities of these platforms.

Fig. 1. The Analog Discovery and Analog Discovery2 platforms

Fig. 2 presents the Analog Discovery platform versus traditional test equipment. The platform can successfully replace traditional equipment that can be found in a college lab.

Fig. 2. The Analog Discovery platform versus traditional test equipment

The experiments and associated tutorials using the Analog Discovery Board are available to the students through Black Board Learn Course Management Systems.

The first set of experiments was designed for the Electrical Circuits courses. The experiments duplicate the experiments presented in the EET 111 and EET 113 lab manuals using traditional equipment, trying to minimize the learning curve for the students, such as building circuits, connecting equipment, troubleshooting, taking and recording measurements.

EET 111-Electrical Circuits I and EET 113-Electrical Circuits II are four credit freshman courses. They are covering DC circuits (EET 111) and AC circuits (EET 113). First course covers Ohm's and Kirchhoff's Law, series and parallel connections, circuit mesh and node analysis, DC maximum power transfer, while the second course cover sinusoidal waveforms, average and rms values, phasors, R-L-C networks under sinusoidal steady state conditions, series and parallel resonance, complex power, passive filters, etc. For both courses, the traditional lab experiments follow closely the topics covered in the theory courses and students learn how to build and debug electrical circuits using traditional lab equipment such as power supplies, multi-meters, oscilloscopes, and function generators.

As the enrollment continues to grow every year, more and more students are using the laboratory equipment, teams tend to become larger, and equipment availability is becoming a

problem. Missing labs also is not an unusual phenomenon among students, especially in the freshman year.

Students enrolled in these courses interested to do the labs that they missed and to explore theoretical course concepts can borrow Analog Discovery platforms from the instructor and they can keep them for the entire semester. Students are also provided with components needed to perform different experiments. Students sign an agreement, instructing them how to return the platforms at the end of the semester.

A "snippet" of a tutorial for **EET 111-Electrical Circuits I** is presented below. Through extensively detailed step-by-step tutorials, students learn how to build and test DC electrical circuits, using the instruments provided by the Analog Discovery platform. *Note: Figures in the "snippets" follow the notation in the lab manual*.

Voltage Measurements-Voltage Divider Rule

Set up the circuit presented in Fig. I. Apply 5 V_{DC} to the circuit from the voltage supply of the Analog Discovery platform. In this experiment R_1=1K Ω and R_2 = 2.2K Ω.

- Insert resistor **R1** and the **+5V** input in node **A** (red wire V+);
- Insert resistor **R1** and **R2** in node **B.**
- Insert the resistor **R2** and ground **GND** in node C (black wire GND).

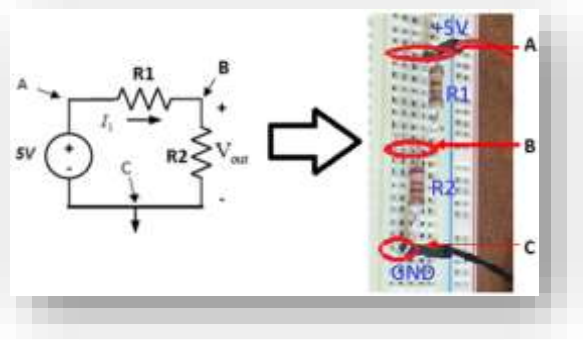

Fig. I

- Connect the **"1+"** (orange wire) connector to node **A.** Connect the **"1-"**(orange-white wire) connector to node **B**..
- Repeat for resistor R2. Connect the **"1+"** connector to node **B**.
- Connect the **"1-"**connector to node **C**. See Fig. II.

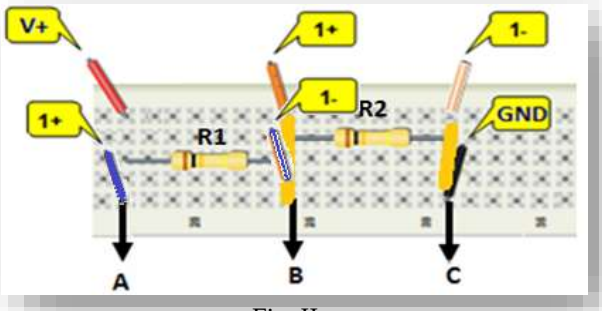

Fig. II

Note: Nodes **1+** and **1-** are connected to the voltmeter. They are attached to measure the voltage drop across R1 and R2 respectively. You can use **"2+"** (blue wire) and "2-" (blue and white wire) to measure V_{R2}=$V_{out.}$ The voltage source supplies 5 V_{DC} (red wire +5V, white wire -5V).

- Open **Wave Forms ™** to view the main window. See Fig. III.

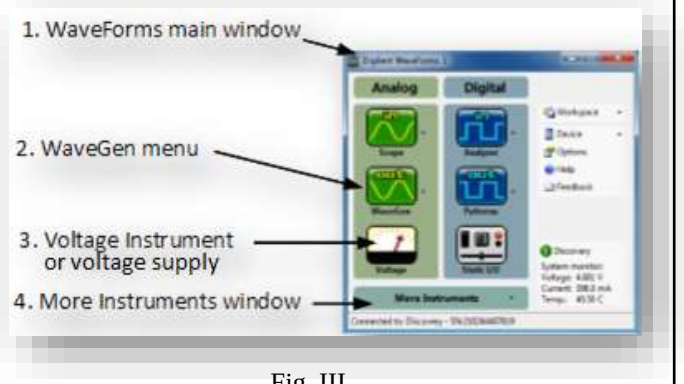

Fig. III

- Open the **Voltage instrument** and set the V+ *ready* (**Rdy**) and Power **ON** as shown in Fig. IV.

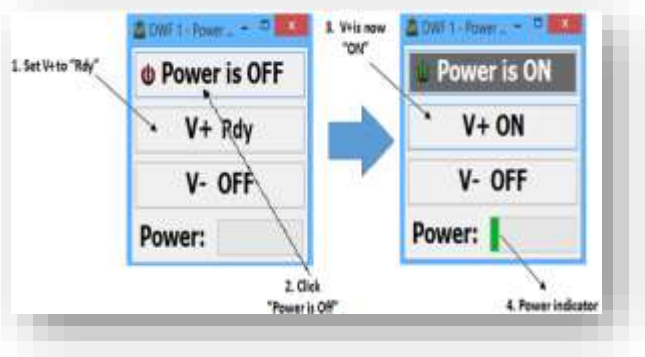

Fig. IV

From WaveForms Software, select more instruments. Select Voltmeter option. Get the readings from DFW1 Voltmeter -Channel 1 DC and compare with your calculated values. See Fig. V.

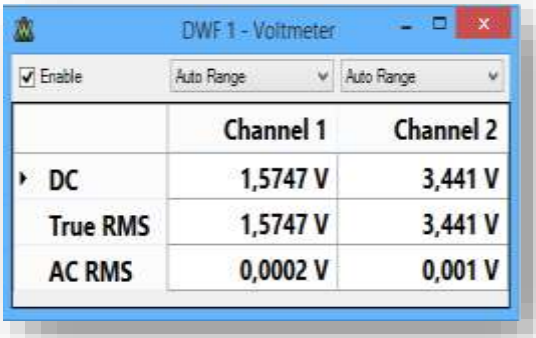

Fig. V

The experiments and associated tutorials for **EET 113-Electrical Circuits II** course are similar with the previous ones. Students build and debug AC circuits using traditional lab equipment at school and using the Analog Discovery platform at home. They learn how to use the Function Generator to generate electrical signals and how to use the Oscilloscope to measure electrical signals.

"Snippets" of the tutorials for the EET 113 course are presented below. The first one presents basic functions of the oscilloscope, while the second one presents a Resistor-Capacitor series circuit experiment.

The Oscilloscope

The oscilloscope is selected from the main window -**Wave Forms** ™ (presented in the previous tutorial).

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Adjust Time Scale: The time scale can be controlled by just clicking on the time box located at the upper right side of the window. See Fig. I.

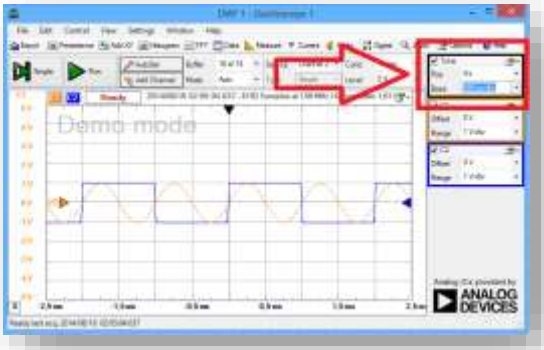

Fig. I

Click on Run to acquire and display data on the oscilloscope window. See Fig. II.

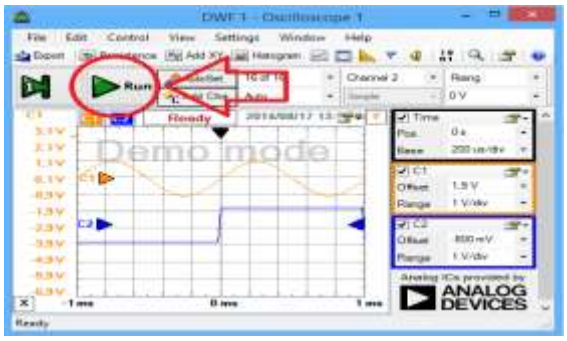

Fig. II

RC Series Circuit

- Build the circuit presented in Fig. I:

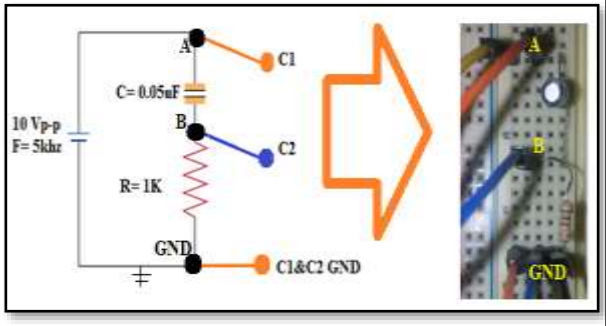

Fig. I

- Calculate the capacitive reactance (**Xc**), the total impedance's magnitude and phase angle of the series circuit (**Z**), the phase angle between current and voltage **(θ)**, the current phasor **(I_T)**, the phasor voltages **V_R** and **V_C** and record them.
- Open the function generator (**WaveGen**). Change the voltage amplitude to 3 V (6 Vp-p) and the frequency to 1 KHz. Make sure the offset is set to zero. Supply input voltage (sinusoidal waveform) to the circuit. Click on **Run AWG1**.
- In order to actually see the current waveform, add/generate a Math Channel. Open the scope. Right click in the channels section. Select Add Mathematical Channel and then Click on custom. See Fig. II.

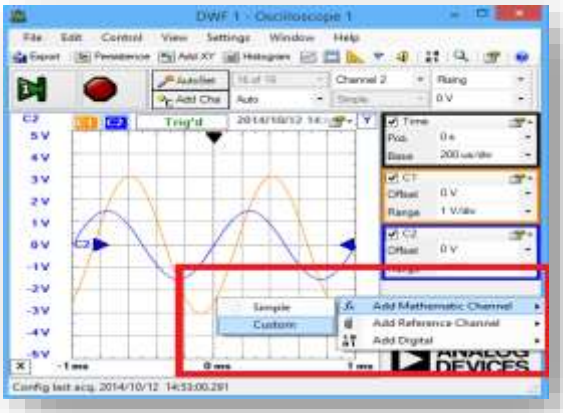

Fig. II

The second set of experiments was created for the Digital Electronics courses. **EET 105-Introduction to Digital Electronics** is a two credit course, offering freshman students "hands-on" experience through one hour of theory/week and three hours of lab/week. The objective of this course is to introduce students to the fundamental concepts of digital electronics, specifically to combinational logic circuits. It covers topics such as: number systems, logic gates, Boolean algebra, arithmetic circuits, code converters, decoders, encoders, multiplexers.

EET 223-Digital Electronics is a four credit sophomore course. The main objectives of this course are the analysis and design of combinational and sequential logic circuits, with an emphasis on sequential circuits such as latches, flip-flops, registers, counters. Students are also introduced to Integrated Circuits (ICs) electrical characteristics. During the lab sessions in both courses students implement and test digital circuits using 74HCxx ICs and PB-501 Circuit Trainer.

"Snippets" of the tutorials for the EET 105 and EET 223 course are presented below. They are similar with the tutorials using the PB-501 Circuit Trainer.

The OR Logic Gate

- Place a 7432 quad OR gate chip on the breadboard, and correctly identify the corresponding pins to one gate. See Fig. I.

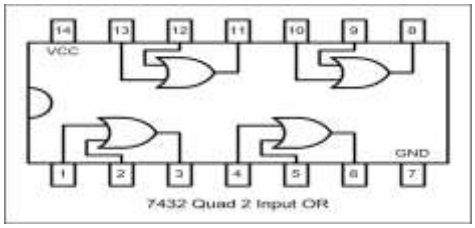

Fig. I

- Locate the wires on your Analog Discovery platform labeled V+, ARROW, 0, 1, and 8. Connect the wires from the platform to your breadboard like in Fig. II.
  -Solid Red Wire labeled V+ to VCC pin.
  -Solid Black Wire labeled Arrow to GND pin.
  -Solid Pink Wire labeled 0 to one input of the OR gate.
  -Solid Green Wire labeled 1 to the other input of the OR gate.
  -Pink Wire w/White Strip #8 the output of the OR gate.

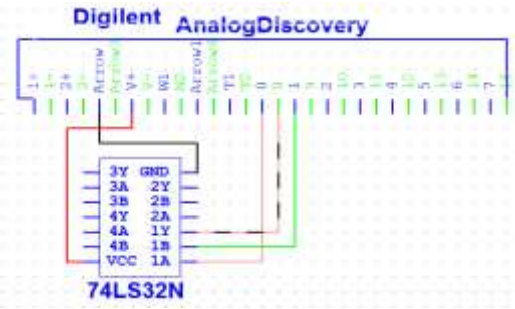

Fig. II

- Start the WaveForms software. Using the switches on the Static I/O to correctly enter the values in your table and see the output values on LED. See Fig. III.
- Record these values in Table 1.

TABLE 1

A		B	Y
0		0	
0		1	
1		0	
1		1	

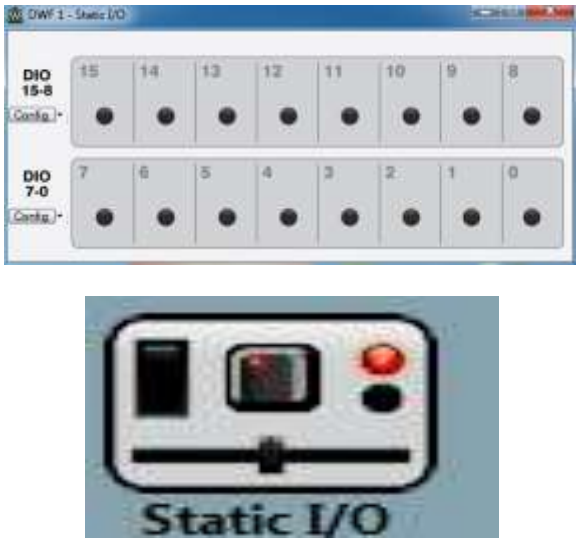

Fig. III

Additionally, a set of experiments was created for **EET 493-Design for Reliability and Testability of Digital Systems** course, a 4xx level technical elective course, that was offered for the first time in the academic year 2016-2017. The course covers techniques and methods of designing reliable and testable digital systems. The second part of the course introduces students to concepts such as: Testing and Testability; Test Procedures; Functional and Parametric tests; Testability measures, etc.

Experiments were designed to help students understand AC and DC electrical characteristics of logic ICs, how to "read" and understand the manufacturer's data sheet, how to compare measured values with the data sheet's values and how to interpret the results. Student use the Analog Discovery platforms at school, with the option to borrow the platforms to work at home.

A "Snippet" of a tutorial for EET 493-Design for Reliability and Testability of Digital Systems is presented below.

In this lab students learn how to measure the *transfer characteristics of an inverter* (using a 2-input NAND gate with the inputs tied together). Students will measure the *DC characteristics of standard CMOS and TTL logic families*, as well as a device that exhibits hysteresis, specifically, an inverter that has a Schmitt Trigger input.

- Place a SN74HC00N CMOS Quad NAND Gate chip on the breadboard. Select one of the four NAND gates for your tests, and tie its inputs together. Connect all unused inputs to the ground.
- Locate the following pins on the Analog Discovery device: 1+ (The Oscilloscope input #1), T1 (The Waveform Generator output #1), V+ (Vcc) and Arrow (Ground). Connect the wires from the trainer to your logic gate as described below:

Solid Yellow Wire labeled V+: Connect to VCC pin.
Solid Black Wire labeled Arrow: Connect to GND pin.
Solid Yellow Wire labeled W1: Connect to the inputs of NAND gate.
Solid Orange Wire labeled 1+: Connect to the inputs of the NAND gate.
Solid Blue Wire labeled 2+: Connect to the output of the NAND gate

- Configure the Waveform Generator to create a triangle waveform that swings between 0 and 5V at a frequency of 100 mHz (Hint: You will need to adjust the offset). See Fig. I.

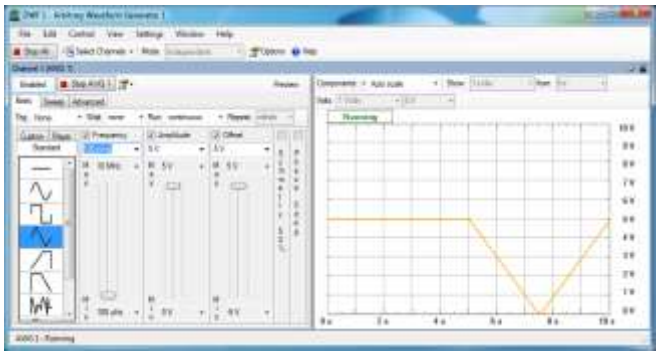

Fig. I

- Start the Oscilloscope. Set Time Base to 1 s/Div. Set the Ch. 1 offset to -5 V and the Range to 2 V/Div. Set the Ch. 2 offset to 0 V and the range to 2 V/Div.

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- Observe the input and output signal of the logic gate on the Oscilloscope. See Fig. II.

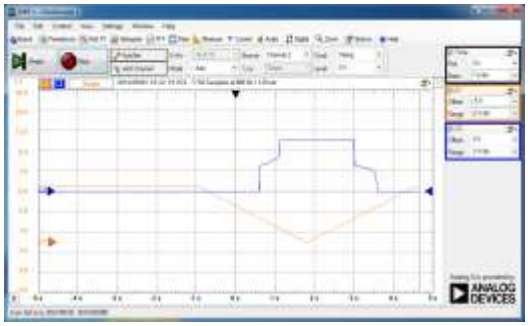

Fig. II

- Click the "Add XY" button to compare the two channels. X is set to Channel 1, and Y is set to channel 2. See Fig. III.

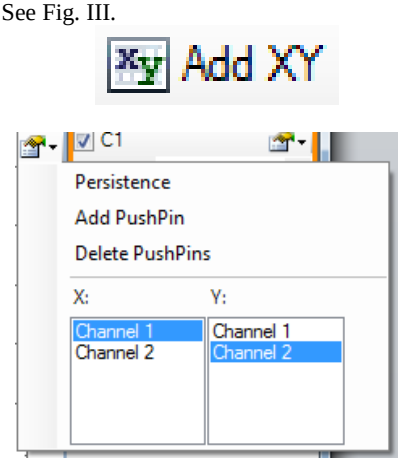

Fig. III

The transfer characteristics of the logic inverter is presented in Fig. IV.

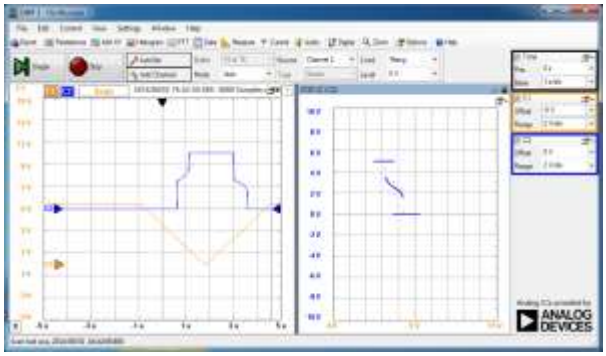

Fig. IV

As work in progress, a new set of experiments are developed for **EET 316-Digital Design** course. In the Digital Design class, students design and implement digital circuits using VHDL language and Nexys3 FPGA platforms. Fig. 3 presents the settings of the experiments. After performing functional verification, students can compare simulation results with real waveforms, using the logic analyzers from the Analog Discovery platform.

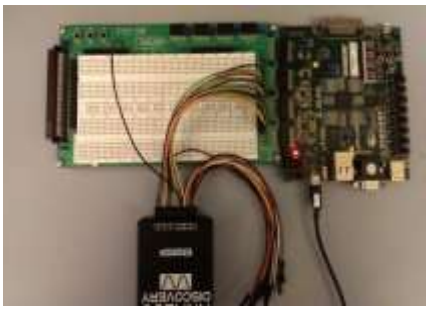

Fig. 3. Setting for the Digital Design experiments

V. RESULTS

The study was conducting starting in the academic year 2013-2014. Only the courses and the associated laboratories that were taught by the same instructor were considered for the assessment. The content of the courses and the associated laboratories did not change during these academic years. Additional data were collected from students' research experiences, trying to strengthen the results of the study.

The characteristics of incoming (freshman) student population at FSC did not change over the last years in terms of GPA, SAT or ACT test scores [28].

A. Assessment Data

The presented data were collected from the courses and labs that the first author of this paper was assigned to teach since the study was initiated.

For EET 113-Electrical Circuits II course, base-line data were collected in the academic year 2013-2014. In the spring semester of the academic year 2014-2015 students enrolled in this course were introduced to the Analog Discovery platform for the first time. In the academic years 2014-2015 and 2015-2016 about 30 % of the enrolled students requested platforms to work at home. The average size of this freshman class is 25 students.

Students' final exam grades and lab practical exam grades in the academic years 2014-2015 and 2015-2016 were compared with baseline data from the 2013-2014 academic year.

Students' knowledge was assessed from final exam's selected questions. The goal for the course is that 70% of the students to meet the course assessment standard, which states that an overall score over 84 % exceeds the standard, an overall score between 70 % and 84 % meets the standard, an overall score between 60% and 69% approaches the standard, while an overall score below 60 % does not meet the standard.

The selected questions were related to the design and analysis of Low Pass Filters (LPF) and High Pass Filters (HPF). Lab experiments and the lab practical exam covered these subjects prior to the final exam. For the lab practical exam, students were tasked to build and measure the characteristics of a Low Pass Filter. Table I presents the average grades for the final exam and lab practical exams. Final exam's selected questions were included also.

TABLE I

Academic Year	Final exam grade (100 points)	Final exam question (LPH) (10 points)	Final exam question (HPF) (10 points)	Lab practical exam (10points)
2013-2014	62.45	6.61	6.275	6.95
2014-2015	71.42	7.86	7.13	7.65
2015-2016	73.62	7.26	7.10	8.93

A positive trend can be observed from the first to the third year of the study. Students average grades for the final exam increased by about 10 points from the first year to the last year of the study. Students average grades for the lab practical exam increased by about 2 points from the first year to the last year of the study. It is important to notice that the students who used the platforms at home got perfect scores in the lab practical exams. They were also among the students who finished first the lab practical exam.

Fig. 4 presents the grades distribution for the selected questions. Problem 1 asked students to analyze a Low Pass Filter, while problem 2 asked students to design a High Pass Filter.

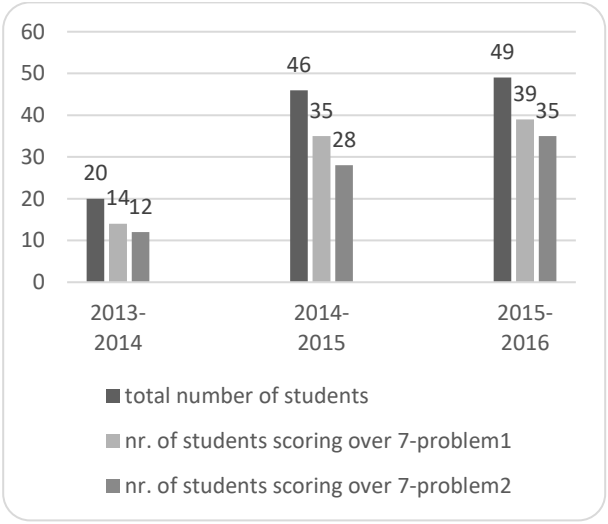

Fig. 4. Grades distribution for EET 113 course

In the academic year 2013-2014, 14 out of 20 students (70 %) scored over 7 points on problem 1 and 12 out of 20 students (60 %) scored over 7 points on problem 2. In the academic year 2014-2015, 35 out of 46 students (78 %) scored over 7 points on problem 1 and 28 out of 46 students (61 %) scored over 7 points on problem 2. In the academic year 2015-2016, 39 out of 49 students (80 %) scored over 7 points on problem 1 and 35 out of 49 students (71 %) scored over 7 points on problem 2. It is interesting to note that students scored higher on the first problem (analysis of a LPF-covered by the lab practical exam), than second problem (design of a HPF). The goal for the course was fully met in the 2015-2016 academic year.

Base-line data for EET 105-Introduction to Digital Electronics course were collected in the academic year 2013-2014. In the fall semester of the academic year 2015-2016

students enrolled in this course were introduced to the Analog Discovery Platform. About 30 % of the enrolled students requested platforms to work at home. The average size of this freshman class is 25 students.

Table II presents the average grades for this course for final exam and second midterm. This course offers freshman students sufficiently "hands-on" experience during three hours of lab per week. The lab practical activities represent the main component of this course, reflected in students' average scores.

TABLE II

Academic Year	Final Exam (100 points)	Midterm Exam 2 (100 points)
2013-2014	73.71	74.12
2015-2016	80.8	83.6

A positive trend can be observed. Students average grades for the final exam and midterm exam increased by 8-9 points, when students had access to computer-based-test equipment at home.

Fig. 4 presents the grades distribution for the midterm term and final exam for EET 105 course.

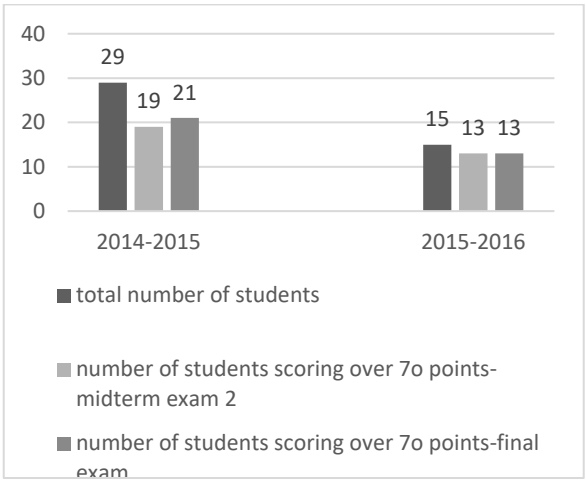

Fig. 5 Grades distribution for EET 105 course

In the academic year 2013-2014, 19 out of 29 students (65 %) scored over 70 points on the midterm exam and 21 out of 29 students (72 %) scored over 70 points on the final exam. In the academic year 2015-2016, 13 out of 15 students (87 %) scored over 70 points on the midterm exam and 13 out of 15 students (87 %) scored over 70 points on the final exam. The students who took the boards at home were in the upper echelon of the course, scoring an average of 85 on their exams.

For EET 493-Design for Reliability and Testability of Digital Systems course end of semester students' survey conducted in the Spring of 2017 showed great appreciation for the course and instructor, students asking for more practical applications. New lab experiments will be created for this course, which will be offered again in the spring of 2018. Students' comments include: "*More labs to further understand the material ","So far I think if there should be more practice and labs the course will be super good".*

Additional data were collected from students' research experiences. All the undergraduate students mentored by the first author of the paper and involved in undergraduate research received Analog Discovery platforms to work at home. Over the last four years, twelve students, from freshman to seniors were mentored through research activities. The undergraduate research performed by students requires designing and implementing systems using microcontrollers, sensors, actuators and other hardware devices. It involved building and debugging various analog and digital circuits. By using these platforms at home, students were able to work faster and obtain outstanding results, leading to conference presentations, a journal publication, securing internships, scholarships, acceptance to graduate school and engineering jobs with prestigious companies in the New York metropolitan area.

Students engaged in the area of smart house design worked on research focusing on: (i) efficient use of resources; (ii) authentication and security; (iii) safety; (iv) human interaction (v) increased comfort and support for vulnerable people. Example of presentations and publications include:

-"*Smart Energy House*", presentation at the 2015 IEEE International Energy and Sustainability Conference. Students won the Outstanding Student Poster Award

-"*Smart Energy House*", presentation at the Brookhaven National Laboratory, 2016.

-"*Design and Implementation of a Reliable and Environmental Friendly Smart House System*", published in the International Journal of Smart House, 2017.

-"*Design and Implementation of Smart House System for Vulnerable People*", presentation at the International Conference on Remote Engineering and Virtual Instrumentation, 2017.

-"*Smart House System: Enhanced Living*", presentation at the 2017 IEEE International Energy and Sustainability Conference.

Students involved in this research received internships at Brookhaven National Laboratory, scholarships such as D3 scholarship and Barnes&Noble STEM scholarship, and were accepted to engineering graduate programs at SUNY Stony Brook and Farmingdale State College.

B. Challenges

The main challenge (logistic issue) was retrieving the platforms from the freshman students at the end of the semester and making sure that enough platforms are available during one semester, for two courses.

C. Lessons Learned

For the freshman courses it is very important to start earlier in the semester to encourage students to try "hands-on" experiments outside the traditional laboratory settings, to spend more time doing in-class demonstration at the beginning of the semester and to continuously remind them about the benefits of "hands-on" experience.

D. Final Results

The results of the study suggest that engaging students in active, experiential learning offers an effective way to educate undergraduate students. This leads to better results, in terms of

graduation, retention, and employability. Farmingdale State College's most recent survey of alumni reveals that 89% of baccalaureate degree recipients are employed within six months of graduation; 74 % percent are employed at a position related to their degree [28].

VI. Conclusions

This paper presents an active learning experience using a set of experiments covering courses from the lower to the upper level division in the areas of electrical circuits and digital electronics. The experiments and associated tutorials have the potential benefit to help students to achieve a higher level of learning and to develop essential employability skills The Analog Discovery platforms and associated experiments will be made available to the students in the next five-six years and/or as long this technology is modern and efficient. The model can be adopted by other schools and engineering departments.

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