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Diffusion of Mobile, Hands-on Teaching and Learning in Puerto Rico: First Year Results

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Dr. Yacob Astatke completed both his Doctor of Engineering and B.S.E.E. degrees from Morgan State University (MSU) and his M.S.E.E. from Johns Hopkins University. He has been a full time faculty member in the Electrical and Computer Engineering (ECE) department at MSU since August 1994 and currently serves as the Interim Associate Dean for Undergraduate Studies in the School of Engineering. Dr. Astatke is the winner of the 2013 American Society for Engineering Education (ASEE) "National Outstanding Teaching Award," and the 2012 ASEE Mid-Atlantic Region "Distinguished Teacher" Award. He teaches courses in both analog and digital electronic circuit design and instrumentation, with a focus on wireless communication. He has more than 15 years experience in the development and delivery of synchronous and asynchronous web-based course supplements for electrical engineering courses. Dr. Astatke played a leading role in the development and implementation of the first completely online undergraduate ECE program in the State of Maryland. He has published over 50 papers and presented his research work at regional, national and international conferences. He also runs several exciting summer camps geared towards middle school, high school, and community college students to expose and increase their interest in pursuing Science Technology Engineering and Mathematics (STEM) fields. Dr. Astatke travels to Ethiopia every summer to provide training and guest lectures related to the use of the mobile laboratory technology and pedagogy to enhance the ECE curriculum at five different universities.

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Abstract

This paper discusses the first year results of an initiative to diffuse mobile, hands-on teaching and learning in all five engineering schools in Puerto Rico. The effort addresses engineering courses that have an electrical/electronic circuits component such as electrical networks, electronics, experimental methods, and mechanical vibrations. This effort relies on constructivist methodologies which are based on the widely accepted principle that students construct their own versions of reality rather than simply absorbing versions presented by their teachers. The Analog Discovery Board, essentially a circuits laboratory that fits in the palm of one's hand, is used as the medium to explore course concepts. Two NSF-funded faculty workshops in Puerto Rico serve as the primary means for diffusing the innovation. The first workshop was conducted at Universidad del Turabo in February 2015. The workshop introduced the board and parts kit to 16 participating faculty members from four of the five engineering schools in Puerto Rico. The workshop also provided pedagogical materials that have already been developed for some courses, including videos that can be used in a flipped classroom environment. The workshop was rated as "excellent" with an average score of 4.9 on a scale of 1 to 5. By the end of the first workshop, each faculty participant was ready to immediately start exploring mobile hands-on learning in their classrooms. Twenty Analog Discovery boards and parts kits were handed out to each participating institution to seed the diffusion effort. Results of a survey are presented in the paper. The results include diffusion rates as measured by the number of class sessions the board

was used divided by the total number of class sessions held after the workshop. It also includes comments by the faculty that describe how the innovation was used in the classroom, comments on what held them back from implementing the board more often in their courses, what they liked best and least regarding the entire experience, a list of additional comments, and ideas for a future proposal. The participants are interested and motivated to continue working as a group to advance this innovation in Puerto Rico.

Introduction

This section restates some material from reference [1] to provide context.

Diffusion of educational innovations is a challenge that has defied a satisfactory solution for decades as evidenced by the many references in the literature; for example, Borrego [2] states that "*despite decades of effort focused on improvement of engineering education, many recent advances have not resulted in systemic change*". Felder and Hadgraft [3] state *"... if engineering faculties could be induced to put into practice everything we currently know about teaching and learning …, then we would achieve innovation with impact to an extent beyond the wildest dreams of the most idealistic reformers. The question then becomes, how can we do that?"*

The goal of this project is to ignite state-wide diffusion of mobile hands-on teaching and learning in Puerto Rico through two (2) workshops that will train mostly Electrical Engineering (EE) faculty participants on the use of the Analog Discovery board in the classroom, and related active learning pedagogies, followed by the assessment of implemented educational strategies to determine effectiveness in a Hispanic student setting.

This project builds upon what the Center for Mobile Hands-On Learning STEM has accomplished with Historically Black Colleges and Universities (HBCU) during the past few years [4] and extends a similar model to all the Hispanic engineering schools in Puerto Rico. It is yet to be determined if mobile hands-on learning is universally accepted [4]. This project will provide initial data to test the hypothesis that mobile hands-on learning can be successfully diffused within the Hispanic undergraduate student and faculty community of Puerto Rico.

The five institutions in Puerto Rico are:

1. Universidad del Turabo (host institution)
2. University of Puerto Rico – Mayagüez Campus
3. Polytechnic University of Puerto Rico
4. Caribbean University
5. Interamerican University – Bayamón Campus

The first workshop was conducted on Saturday, February 21, 2015 and included 16 participants from the first four institutions listed above. The second workshop, conducted on Saturday, November 7, 2015, was attended by 21 participants from all five institutions. Both workshops were conducted at the host institution, Universidad del Turabo, from 8:00 am – 5:00 pm.

The first workshop (Saturday, February 21, 2015) introduced the Analog Discovery board and parts kit to the 16 participants. A board, parts kit, and a PC with the required WaveForms software were provided to each participant. The workshop introduced the pedagogical materials that have been developed for mobile hands-on learning, including videos that have been successfully used in a “flipped classroom” environment [5]. The workshop was interactive, just like the transformed classroom is expected to become. Dr. Astatke and Dr. Connor, the workshop providers, shared their experiences with mobile hands-on teaching and learning and worked through two selected pedagogical activities typical of a Circuits I course. By the end of the first workshop, each faculty participant was ready to immediately start exploring mobile hands-on learning in their classrooms. Each institution received approximately 20 sets of Analog Discovery Boards, and an analog parts kit that includes a breadboard, to seed the effort. The WaveForms software is legally downloaded for free from the internet.

The second workshop (Saturday, November 7, 2015), which was attended by 21 participants from all five institutions, started with a presentation by Dr. Astatke regarding lessons learned from the NSF grant to the HBCU’s. It was followed by individual presentations from each institution to share their initial impressions after having used mobile hands-on learning in the classroom in a few class sessions. The workshop concluded with more hands-on activities. The workshop was divided into an introductory session (for first-time users that were not in the first workshop), and an advanced session for the other faculty members. By the end of the workshop the participants had answered some of their concerns and were in position to include additional mobile hands-on pedagogical activities in their classroom. All five institutions agreed that there was merit to write a second proposal to NSF to continue working as a group to advance this innovation in Puerto Rico.

Assessment Results – 1st Workshop

A survey was conducted at the end of the Spring 2015 semester (January 2015 – May 2015) to assess the impact of the first workshop. Spring 2015 was the same semester in which the first workshop took place (February 21, 2015). There were approximately 20 class sessions in which to start implementing mobile, hands-on teaching and learning. The diffusion rate is based on 20 class sessions.

Although there were 16 participants, only 9 were teaching courses in which the innovation could be used during Spring 2015. The courses ranged from Freshman Design for Electrical Engineers to Electronics II. It also included courses in mechanical engineering. The response of these 9 faculty members are presented in this section.

Table 1 includes the number of lecture sessions in which the analog discovery board was used. It also includes the diffusion rate which is calculated as the number of sessions in which it was used divided by 20, the number of sessions in which it could have potentially been used.

Table 1. Usage of the Innovation and Diffusion Rates

	Faculty Members (n=9)									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Average**
Number of sessions	0	0	3	4	0	3	5	2	1	2.0
Diffusion Rate*	0%	0%	15%	20%	0%	15%	25%	10%	5%	10%

* Diffusion Rate is calculated as the number of sessions in which it was used, divided by 20, the number of sessions in which it could have potentially been used. Expressed in percent.

Comments by the Faculty

This section includes comments made by the faculty in the survey. It starts with a list of the courses in which the board was implemented. It is followed by a description on how the innovation was used in the classroom, comments on what held them back from implementing the board more often in their courses, what they liked best and least regarding the entire experience, a list of additional comments, and ideas for a future proposal to extend the effort. The institutions and the specific faculty members are not identified for anonymity purposes and, perhaps most importantly, because the motivation is to learn and work as a group in an attempt to advance this innovation in Puerto Rico.

<u>Courses in which the board was used</u>

Freshman Design for Electrical Engineers
Circuits I
Circuits I Laboratory
Circuits II
Electronics II
Experimental Methods (mechanical engineering)
Mechanical Vibrations (mechanical engineering)
Automatic Controls (mechanical engineering)

Short description on how the board was used in class

- Low-frequency and high-frequency response in a common-emitter BJT amplifier; Active filters.
- Basic concepts of an RC circuit.
- Students used the boards in pairs (two students per device). Created current and voltage dividers with the board and corroborated the theoretical results. Demonstrated how capacitors work.
- Used the function generator and the oscilloscope of the board to see the input and output signal for RL and RC circuits.
- Characterization curve of a diode. The exercise was to show the concept of sinusoidal waves out of phase, and the relationship between apparent power, AC voltage, and AC current. The boards were lent to students so that they could do other lab exercises. The laboratory manual is being modified to include virtual instrumentation. Working to provide the board through the campus bookstore.
- Used in a mechanical vibrations class to find the damping ratio of a cantilever beam using a piezoelectric accelerometer. The integrated Fast Fourier Transform (FFT) was especially helpful.

What held you back from implementing the board more often in your course?

- Late access to the board.
- The fact that the theoretical circuital knowledge of the students in this course does not cover e^{jwt} excitations.
- It is more useful in basic courses such as Electrical Circuits and Electronics I. Next semester I expect to use it more often since I will be teaching Electronics I.
- Lack of time allocated to this kind of exercise in the syllabus.
- Time constraints prevented integrating the device more often. Preparing a class using a new device requires time for preparation. Limited multimeter functions also limited the use of the device.
- The workshop was given after the courses were designed (mid-semester workshop).
- Labview by National Instruments and Arduino fill most of the material for experiments but the Analog Discovery Board will be evaluated for more experiments.

What did you like best about the entire experience?

- Learning something new about the versatility of the board.
- Share experiences with colleagues from different universities in the island. Also, explore new teaching strategies using inexpensive equipment.
- The power of having hardware with both a signal generator and oscilloscopes included in a single device.
- The talks of the flipped classroom were useful.

- The use of the board in class provide hands-on activities where everyone participated in the action during the learning process, creating a more entertaining atmosphere than the usual traditional lecturing. Students had the opportunity to learn how to use the oscilloscope, they were able to see the signals, frequencies, and other parameters that are discussed in the classroom, but are best demonstrated with hands-on activities. Students were able to see how changing input parameters from the signal generator included in the software reflected different responses at the circuit output.
- The best thing about this experience is for students to perform the different labs in the comfort of their homes with only the Analog Discovery Board which has a very low cost.
- Students can have a virtual laboratory anywhere, once they have access to a PC or laptop.
- The ease of using the board, the FFT, the potential to develop a number of experiments with this kit.

<u>What did you like least about the entire experience?</u>

- Some of the connections were a little bit loose. The connectors could be improved.
- Limited multimeter capabilities of the Analog Discovery Board
- Some students cannot afford a laptop or PC, and therefore I had two students that were unable to use the device. Software was not installed in our general use computer laboratories. This situation will be fixed by next semester.
- The accelerated rhythm.
- The whole experience was very good. I wish we could do a longer workshop to learn all the possibilities with the Analog Discovery Board.
- The lack of time

<u>Additional comments</u>

- This is a great tool for the students to have hands-on electronic hardware as well as understand the basics of electronics by touching.
- Extend the idea to more complex experiments.
- Thanks for giving me the opportunity to participate.
- Incorporating the Analog Discovery was a great experience for me and the students. A smart phone app may eliminate the need for a classroom computer. Software can be improved by incorporating more multimeter functions.
- Excellent experience.
- Integration with Labview or other platforms would be a nice integration to expand the capabilities of the board.

<u>How would you use additional funds to continue developing this experience?</u>

- Provide training to students. Provide more boards to students.
- Use of the boards in transient problems.

- Conduct statistical analysis to test the effects of the devise on the learning outcomes. Compare the grades of a section of students that use the device versus a section that does not. Investigate this new method for delivering the course.
- Purchase more boards and spare parts such as batteries, resistors and sensors that are not included in the Parts Kit.
- Develop experiments in mechanical engineering in several courses (instrumentation, controls, vibrations, and strength of materials).

Conclusions

The following conclusions can be drawn from this study:

1. The most encouraging finding after one year of implementing this program is that the engineering faculty of the five engineering institutions in Puerto Rico have enjoyed the experience and have begun using the innovation in the classroom in a variety of courses. The average diffusion rate is a modest 10% but was achieved during the same semester that the workshop was held.

2. The board has been used mostly by electrical engineering faculty in electrical engineering courses. The courses in which the board was used varied from Freshman Design for Electrical Engineers to Electronics II; however, it has also impacted mechanical engineering faculty in three mechanical engineering courses : Experimental Methods, Controls, and Mechanical Vibrations. This unexpected “broader impact” added an element of surprise that was well received by the researchers.

3. The five institutions have adapted well to the framework of the NSF grant that has brought them together. In this framework, the host institution serves as the administrator of the grant and invites the remaining four institutions to participate in the effort. The main advantage of this framework is that it simplifies the administration of the grant. On the other hand, it could be argued that this framework introduces bias by the institution that writes the proposal and holds the grant. This concern is believed to be a minor one since all five institutions, including the grant holder, participate as equals in trying to achieve the intellectual merit of the grant; that is, testing the hypothesis that mobile, hands-on teaching and learning can be successfully diffused within the Hispanic undergraduate student and faculty community of Puerto Rico.

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