Experimental Centric Pedagogy in First-Year Engineering Courses

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Abstract

It is known that a large percentage of students in engineering programs switch their majors in the first two years, due to teaching methodology that is not suitable to the current population of students[9]. Integrating hands-on based learning is one of the key approaches that has been proven to be effective in improving retention by making the learning experience engaging and motivating for students. This paper addresses results of a series of pilot studies that utilized hand-held devices, specifically an Analog Discovery (AD) Board, to support experimental centric, hands-on learning in introductory engineering classes. Pilots of use of the AD Boards were shown to be successful across a variety of instructional settings. The research undergirding the findings for this paper is derived from a collaborative grant-funded project supporting a consortium of 13 public Historically Black Colleges and Universities (HBCUs) investigating the impact of using hands-on experimental-based pedagogical techniques on instruction to teach circuits concepts in introductory engineering classes.

Introduction

There is a staggering underrepresentation of African-Americans in engineering with data showing that African Americans comprise only 5% of all bachelor's degrees in engineering and related fields[1]. In addition, the six-year graduation rate for African Americans in engineering is 38.3% and this low retention rate has been partially attributed to learning environments that are not engaging or motivating the students to learn. The ASEE retention study report concluded that the retention rates could be improved through multiple strategies that include making curriculum and class enhancements[3]. Integrating hands-on based learning is one of the key approaches that has been proven to be an effective classroom and class enhancement approach for retention by making the learning experience engaging and motivating for the student[6,8,14] There are even better benefits for having hands-on learning approaches that use portable equipment in introductory courses, such as Analog Discovery[2] and MyDaq[17] in similar projects such as Lab-in-a-Box[12,13] and TESSAL[11]. Among the benefits are improved student engagement[5,16,18] and improved student learning[19]. The usage of portable equipment also allows the hands-on activities to be adaptable to traditional lecture courses[8,10], lab settings[4,8,11], and homework/project activities[8]. As the main producer of African American engineering graduates, Historically Black Colleges and Universities (HBCUs) play a critical role in recruitment and retention of African American engineering students and as a result, there is now in progress a simultaneous implementation of hands-on learning approaches at multiple campuses[9].

The portable equipment used in this study (Digilent's Analog Discovery) is a full set of test and measurement devices (a 5MHz, 2-channel oscilloscope; two arbitrary waveform generators, ±5V DC power supplies; 16 digital I/O channels; a spectrum analyzer; a logic analyzer; a network analyzer; a DC voltmeter) equivalent to much more expensive desktop instruments when connected to a laptop computer through its USB port. While the displays produced using this small device (about the size of a deck of playing cards) are found on the computer screen, there is nothing simulated; all measurements are as real as those from benchtop instruments. The low cost and portability of this equipment, also usefully described as personal instrumentation, enable the delivery of experimental centric, electrical and computer engineering educational experiences in almost any context, including fully online[26].

Klingbeil and Bourne[23] found that a problem-based learning curricula has made the greatest impact on students from underrepresented groups in the science, technology, engineering, and mathematics (STEM) disciplines. Additionally, participants in the problem-based learning (PBL) courses of a first-year engineering course had higher mathematics placement scores and more than double the average graduation rate of students at the participating institution. In a study of a single university site evaluation of teaching practices, Nasr and Ramadan[24] found students who were instructed using PBL performed higher on the majority of questions on course final examinations than students taught using the subject-based learning (SBL) approach. Hora and Holden[22] acknowledge students' types of *cognitive engagement* correspond with usage of different technological tools and teaching behaviors and methods.

To engage freshman students and to motivate them to persist in engineering, Experimental Centric Pedagogy enabled with the AD Boards was introduced into first year engineering courses at 13HBCU institutions. A similar approach has also been implemented in core circuits and electronics courses, design and project courses and similar courses serving engineering and science students both inside and outside of ECE.

Purpose of the Paper:

The purpose of this paper is to present results from a series of pilot studies. Data sources included post surveys from 86 students at 4 selected institutions, reviews of curriculum modules used in classes, and interviews with faculty/instructors and students at 5 institutions. Outcomes studied included a series of variables that reflected both precursors to learning, immediate outcomes, and initial long term outcomes.

Background of the Study

In 2013, Howard University, in collaboration with 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, received funding for a National Science foundation (NSF) grant entitled, "*Experimental Centric Based Engineering Curriculum for HBCUs*." The project advances a process which will create a sustainable "HBCU Engineering Network" that is focused on the development, implementation, and expansion of an experimental centric instructional pedagogy in engineering curricula used in these HBCUs.

The goal of the project is to increase the number of highly qualified and prepared African American engineers, and all students, to have a better understanding of technology and its role in STEM education and the policy associated with it. Another key goal for the grant is to promote wide spread dissemination of portable hands-on mobile devices through proactive collaboration between educational institutions and industry partners. Collaborating partners are each using portable hands-on hardware coupled with a model of pedagogy (i.e., blended learning - a combination of lecture and hands-on activities in class; traditional - hands-on activities are completed outside of class time; etc.) to provide instruction in their courses.

The project envisioned that one method for motivating and engaging freshman students is to use the AD Boards. The pedagogy allows students to learn basic laboratory skills and be introduced to basic circuit analysis concepts and electronics. Some typical examples follow.

The Introductory Electrical and Computer Engineering classes at Prairie View A&M University (ELEG 1021) and at Howard University (EECE 102) use the Electrical Engineering (EE) Practicum[4]. The EE Practicum is a cloud-based book with experiments that uses the Analog Discovery module and electronic parts kit to facilitate hands-on learning and self-exploration by the students. The Analog Discovery module enables students to quickly test real-world functional circuits anywhere and anytime with their own personal computers.

The EE Practicum provides the students the laboratory skills, and also allows the students to explore and experiment in the areas of circuit analysis and electronics. In the area of basic circuit analysis the students learn: (i) Ohm's Law, (ii) voltage divider rule, (iii) current divider rule, (iv) charging and discharging of a capacitor in an RC circuit, (v) resonant RLC circuit. The EE Practicum also introduces the students to basic electronics such as: (i) semiconductor diodes and LEDs, (ii) half-wave rectifiers, (iii) Op Amp inverting and non-inverting amplifiers, and (iv) envelope detection circuits. The students also experiment with electronic sensors such as: (i) TMP01 Thermal Sensor, (ii) ADXL237 Accelerometer, (iii) GT0950RP3 Speaker and ADMP504 Microphone. The students are able to master the following laboratory skills: (i) read resistor values by using resistor color code, (ii) build electrical and electronic circuits using breadboard, (iii) use instruments, such as arbitrary waveform generator, scope, power supply, voltmeter, network analyzer, and (iv) obtain Bode Plots by using a network analyzer. Two examples from the EE Practicum are shown in Figures 1 and 2. To learn basic laboratory skills and the use of LEDs, the students built the waveform polarity indicator circuit shown in Figure 1. Figure 2 shows the Bode plot obtained from the RLC circuit by using the Network Analyzer of the Analog Discovery Board. Bode Plots are not extensively studied at this introductory level. Rather they are used to help first year students develop a basic understanding of frequency dependence in circuits and the concept of phase, which is also addressed using time-dependent voltages at specific frequencies.

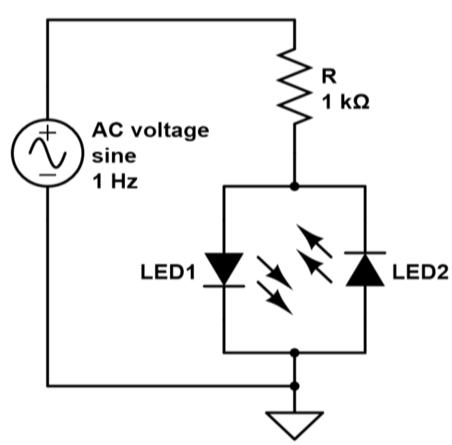

Figure 1: Waveform Polarity Indicator Using LEDs.

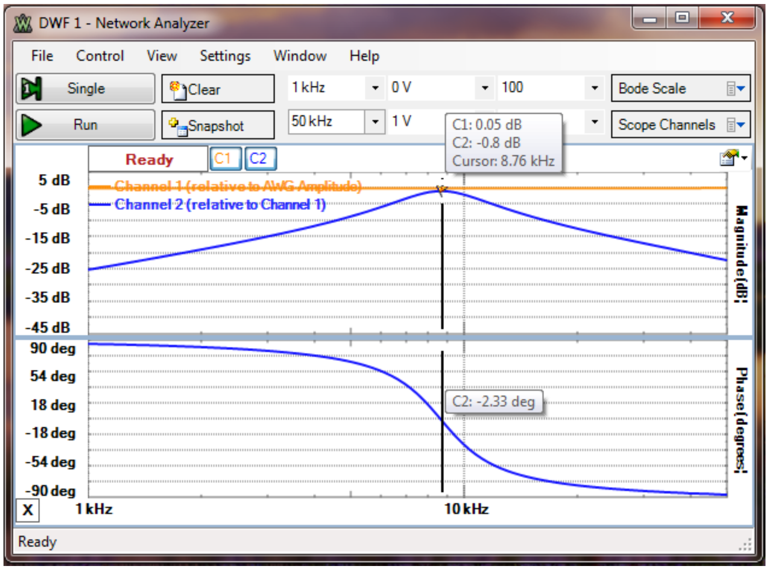

Figure 2: Magnitude and Phase Response of RLC Circuit

Florida A&M University has an introductory engineering class (EGN 1004L) that uses the AD Board to perform projects. One of the projects is to verify the principle of superposition. First, students are asked to build the circuit represented by the schematic in Figure 3 on a breadboard, measure voltages V_a and V_b, and compute the current going through resistor R_L. The voltage sources are made using the arbitrary waveform generator feature (WaveGen) of the AD Board by connecting the W1 generator to node 1 and the W2 generator to node 4. (W1 and W2 are the output labels for the AD function generators.) Then, each voltage is deactivated by setting the voltage to zero and, in each case, V_a and V_b are measured again and the current going through resistor R_L is recomputed. All the data is collected in a table and students have to verify that the current going through resistor R_L when both sources are activated is equal to the sum of all currents when the voltage sources are independently set to zero. This project can also be extended to verify the linearity of voltages V_a and V_b with the voltage of the two sources.

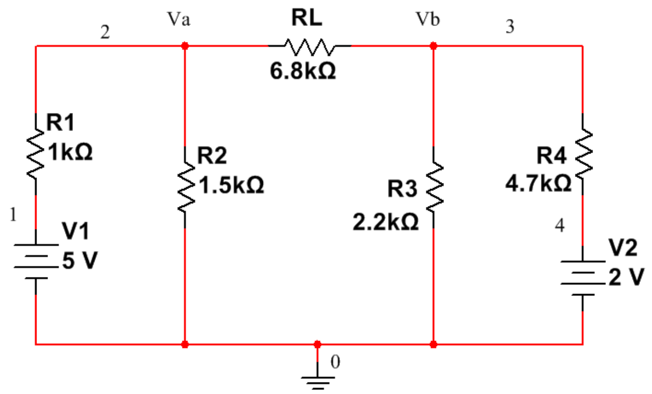

Figure 3: Experiemental setup with two voltage sources used to verify the principle of superposition.

Other projects done in introductory engineering class at Alabama A&M University (EE 101) involve (i) demonstrating the relationship between pure-tone sinusoidal signals and the perceived sound, including the amplitude and frequency effects; (ii) the synthesis of beat frequencies by adding and/or subtracting two proximate tones; (iii) listening to various periodic signals including square and triangular waveforms and compare to pure tones with corresponding frequencies. These experiments help beginning students to make connections between mathematics and real world problems. It also motivates students to strengthen their basic understanding of signals and circuits.

Implementation of the Analog Discovery Board in Experimentally Based Introductory Engineering Classes

Participants

The researchers piloted AD Boards and supporting curricular modules in several instructional/degree granting HBCU settings. Classes included introduction to engineering and introduction to electrical engineering content offered by Departments of Electrical Engineering and Schools of Engineering. The instructors varied in age but all had prior experience with content. All participated in at least two workshops where they learned and practiced how to use the AD Boards. Engineering educators experienced in the delivery of circuits and electronics intensive courses using Analog Discovery, Mobile Studio and myDAQ shared their content and lessons learned as they explored the wide variety of educational delivery made possible by low-cost, portable and personal instrumentation. They also developed and shared content and experiences through a common website and bi-weekly online meetings organized by the 13 HBCU engineering partners in a collaborative project. Materials developed by other educators and collected by colleagues from partner institutions were also shared through the website and meetings.

To obtain data for the evaluation of the project, the researchers distributed Experimental Centric Engineering Curriculum (also called ECP, for Experimental Centric Pedagogy) Pre- and Post-Surveys to students enrolled in introduction to electrical engineering courses at four HBCU institutions. In the Pre- and Post-Surveys the respondents submit demographic information, complete a Likert-type evaluation of Materials/Techniques, Engineering Knowledge, Use of Portable Hands-On Hardware, and Effects of the Integration of Hands-On Hardware, rate the overall effectiveness of the project, and respond to open-ended questions about the students' usage of the devices. Additionally, the researchers used the ECP for HBCUs Classroom Observation Protocol. All research instruments were developed by Newman and Gullie (2013) for evaluation of the project. The reported results include findings on 86 students from four institutions over two terms. The results were captured from five separate course sequence numbers taught by four instructors. Researchers conducted additional observations and interviews with faculty and students at two other HBCU sites.

Table 1 shows the demographic information about the students in the introductory classes. The majority of students were male (80%); 75% self-reported ethnicity as Black, 7% as Hispanic, and 4% as multi-racial; the remaining students reported as Asian (7%) or White (7%). Of the students involved, 19% indicated that English was not their primary language. The majority of students were 1st year or 2nd year higher education students; 63% of the enrollees in the introduction to engineering classes were majoring in electrical engineering; 35% identified as computer science or mechanical engineering majors. Upper division (3rd and 4th year students) enrolled to get experience with the new style of course. The graduate/5th year students listed took the course as part of their training as teaching assistants. The remaining students generally reported majors related to other STEM majors for which the course served as an elective or to fulfil a minor requirement.

Table 1
Student Demographics Introductory Class Pilots (n=86)

Gender	**Gender %**	**Discipline of Study**	**Major %**
Male	80	Electrical Engineering	63
Female	20	Computer Science	20
Ethnicity	**Ethnicity %**	Mechanical Engineering	15
Black	75	Other	2
Asian	7	**Degree Progress**	**Degree %**
Multi-racial	4	1st year	63
White	7	2nd year	13
Hispanic	7	3rd year	9
English Primary Language	**Language %**	4th year	12
Yes	81	Graduate/5th year	2
No	19		

Application of the Analog Discovery Board

At the four sites, pilots of use of the AD Boards, as a tool to support experimental centric learning practices within introductory engineering and introductory electrical engineering content, were successful across a variety of instructional settings and uses. Verification and validation of these uses is based on instructor description, student identification and evaluator interviews and review of curriculum. The most frequently occurring pilot settings in which use occurred were traditional classrooms, lab settings, and as part of assigned homework. Table 2 shows the instructional modalities of the AD Boards. Instructors of the classes tended to have multiple semesters of prior experience in teaching both the introductory class content and in using the AD Board. For these instructors, the greatest shift was in piloting an experimental centric approach as part of the teaching methodology within an introductory course, or, for some, in using the AD Board as the experimental tool for students at this level. Within these pilot classes, the typical student experienced a median classroom use of 6+ times per term while use within lab settings usually occurred 8+ times per term.

Table 2
Use of AD Board in Varied Instructional Modalities:
Median Reported Use

Instructional Modality	**Median Response**
Location/Setting of Use*	
In a class setting	6+ times
In a lab setting	8+ times
As part of homework assignment	4+ times
Method of Use*	

Instructor Demonstration	4+ times
Cooperatively with a peer	8 + times
Independently	5+ times

**selection of multiple responses allowed*

The independent use of the AD board (5+ times in Table 2) was reported in interviews as learning style issues motivated by both curiosity and the desire to be accurate. Learning styles were not tested in this study, but individual exploration of course content using similar portable instruments has been connected to learning styles in previous work[27].

Additionally, introductory students typically had 4+ uses of the AD Board as part of their assigned homework. These numbers are markedly higher than use by students in circuits content-related classes as reported by Connor, Newman et.al (2016). In these advanced classes, in-class use was typically 3 times per term while lab use was 5+ times per term. Homework use was slightly higher in circuits-related classes—5+ times per term. These differences in frequency of use may be indicative of the role of instructor familiarity and confidence in using hands-on materials and experimental approaches. Overlapping or simultaneous use of the AD Board varied by institution.

Method of use also varied by site and was found to vary within each of the settings. The key methods of use included instructor demonstration cooperatively with a peer and independently. Cooperative use, described by instructors and TA, usually reflected dyad and triad exploration, occurred in both classroom and lab settings, and was typically experienced by introductory at least 8 times per term. Independent use generally occurred at least 5 times per term; these uses occurred generally in lab/classroom settings, with independent homework use more infrequent. Use of the AD Board as a support for experimental centric instruction via instructor demonstration also was found to occur at least 4 times per term for the typical student. Instructor and student interviews, and a review of module descriptions indicate that in many cases these instructor demonstrations were used as advance organizers to increase student interest and motivation, to prepare students for use in lab settings, and to review potential uses in the real world. Instructors also used demonstrations to present solutions to common problems, to help students rehearse knowledge, and to re-focus the class on a particular topic. Advanced organizer uses frequently referenced real world problems and future needs in advanced classes. Reported frequencies and variations of use by methodology was slightly higher than that found for circuits classes, especially cooperative use with a peer (5+ circuits; 8+ introductory classes). Again this content may reflect both the adaptability of the method and tool to the content but also may reflect the more advanced stage of use based on familiarity and practice of the instructor.

Outcomes/Findings

Table 3
Student Perceptions of the Process of Use

Instruction and Supplementary Materials	**% Agree***
Use was relevant to my academic area.	79
The use of the AD Board reflected course content	77

The AD Board provided opportunities to practice content	76
The use of AD Board suited my learning needs.	74
The use of the AD Board reflected real practice.	71
The time allotted for AD Board use was adequate.	71
Introduction to the AD Board/Supplemental Materials	
Instructions on AD Board use were relevant.	82
Instructions on AD Board use were helpful.	79
Handouts necessary for AD Board use were provided.	75
The visual aids (e.g. diagrams) used with the AD Board were clear and helpful	74

**Number represents percentage of participants who responded "Strongly Agree"/"Agree"; n =86*

Students enrolled in introductory engineering classes viewed use of the AD Board in support of experimental centric learning as a positive experience (see Table 3). Most of the students agreed that use of the AD Board was relevant to their academic area (79%), and reflected course content (77%) as well as real practice in the field (71%). Observations and interviews with instructors indicated that a great deal of effort was invested to be reflective of real practice and the students clearly liked it very much. Three out of four students reported favorable use of the method in that it provided them with an opportunity to practice course content (77%), noting that the amount of time given to practice learning was adequate (71%) and met their learning needs (74%).

A majority of students enrolled in introductory engineering related content courses reported satisfaction with instructions and supplemental materials that were used to support the above uses. Values ranged from 74% (clear and helpful visual aids) to 82% (relevant). All variables received ratings higher than those for students enrolled in circuits' content classes. In that study it was noted that students' favorable ratings of support material increased as instructor familiarity with the process increased.

Instructors of these new pilot classes noted that they used their prior experiences with first time users in advanced content classes such as circuits to help them adapt their introductory material. Most reported using a more in-depth introduction to the AD Boards, providing more hands-on guidance for the first use. Some instructors also develop a separate module, for course credit, that gave the student practice in initial implementation of the AD Board. Faculty of introductory course, in both lab and class settings, indicated that they made a deliberate effort to make sure that students who worked in dyads had equal grasp of AD Board set up.

Short-term Outcomes

Multiple domains of short-term learning known to influence constructivist experimental learning were shown to be supported during these introduction pilots. This included prerequisite affective changes need for learning to occur. A summary of these findings may be found in Tables 4 and 5.

Table 4
Initial Changes Reported by Students

	Perceived Changes	% Agree *
Immediate Learning	My knowledge has increased as a result of use.	79

Prerequisite to Learning	The hands-on AD Board is important in my preparation as an engineer.	79
Prerequisite to Learning	Using the AD Board motivated me to learn the content.	71
Prerequisite to Learning	My confidence in the content area has increased because of use.	70

**Number represents percentage of participants who responded "Strongly Agree"/"Agree" on post-survey; n=86*

In general, three out of four students reported changes relative to affective prerequisites necessary to promote cognitive learning. This included increased attention (e.g. important in professional preparation - 79%) increased confidence in ability to learn the content (70%), and increased motivation to learn the content (71%). Correlated to these changes is a perception that knowledge had increased (79%) which subsequently reinforces attention to, motivation for and confidence in learning, creating an increasingly positive cycle of affective support.

Table 5
How the Method Helped Learning

	Areas of Growth	**% Agree***
General Outcome	Helped me to learn more	88
Immediate Learning	Think about problems in graphical/pictorial or practical ways.	77
Immediate Learning	Learn how AC and DC circuits are used in practical applications.	70
Immediate Learning	Recall course content.	71
Immediate Learning	Improve grades	76
Immediate Learning	Develop skills in problem solving in the content area.	68
Prerequisite to Learning	Develop confidence in content area	73
Prerequisite to Learning	Become motivated to learn course content.	71
Prerequisite to Learning	Confidently complete lab assignments.	70
Prerequisite to Learning	Develop interest in the content area.	64

**Number represents percentage of participants who responded "Strongly Agree"/"Agree" on post-survey; n=86*

As seen in Table 5, when queried, 88% of the students enrolled in the pilot introductory engineering classes reported that the use of the AD Board helped them to learn more. Subsequent follow-up questions as to how the process of use helped to support this learning action related to both affective prerequisites of learning and immediate outcome received high agreement scores.

Actions related to affective prerequisites to experimental learning include helping students to develop interest (64%), to become motivated to learn content (71%), to become confident in learning course content (73%) and more specifically to become confident in completing lab assignments (70%). Specific areas of learning noted included recalling course content (71%), learning about practical applications of AC/DC circuits (70%), thinking about problems in graphical/pictorial/practical ways (77%), and developing skills in problem solving within the content area (68%). These skills were reported by 76% of the students as helping to directly improve their grade. These patterns of self-reported growth for these introductory students reflect values that are similar to those found in advanced classes where commitment to the degree and degree targets is stronger.

Long-Term Outcomes

Changes in support of sustained learning that would transfer to advanced professional study also were noted by two out of three students. Table 6 shows the initial long-term outcomes of this work. Students enrolled in the pilot introduction classes self-reported improvements in working collaborative with fellow students (62%), developing attitudes of self-direction and self-responsibilities (66%) and enhancing their professional abilities (75%). Students also self-reported effects directly related to problem solving and transferring skills related to problem solving; this included developing different ways to solve problems (67%), being able to apply course content to new problems (67%), and transferring their knowledge and skills to problems outside the course (72%).

Table 6
Initial Long-term Outcomes

General Effects of Use of the AD Board	% Agree*
Enhanced my professional abilities	75
Transfer knowledge/skills to problems outside the course	72
Develop different ways of solving problems	67
Apply course content to new problems.	67
Develop attitudes of self-direction and self-responsibility	66
Work collaboratively with fellow students.	62

**Number represents percentage of participants who responded "Strongly Agree"/"Agree" on post-survey; n=86*

Many students in the introductory classes noted that they were aided in this transfer because of their practice with the AD Board, the examples given by the instructor, and their increased confidence in their ability to work in new or varied domains due to their ability to "play" with different problems and find different paths to solutions. Responses of students in the introductory engineering classes were slightly lower than those of students in advanced classes; advanced students also noted the role of practice as important to transfer as well as indicating the importance of pictorial visual memory based on that practice.

Several advanced students noted places in their introductory classes in which experiences with the AD Board would have allowed them to more quickly learn material and advanced concepts. These students generally had worked with introductory students and had observed the experience the pilot students gained and noted that the more experimental "playing" that students obtained in and out of class made a difference in the degree to which they transferred learning to class and professional content.

ABET Indicators

As part of the documentation of student growth directly related to professional outcomes students in the pilot introductory classes were asked to respond to a selected series of ABET student outcomes. Because of the relationship of affective prerequisites and potential outcomes, students were asked to indicate the importance of learning each student outcome and their preparedness in performing that outcome after exposure to and use of experimental centric learning via the AD Board. Results of this comparison indicate that at the end of their experience, the majority of students did not perceive the ABET tasks as very important to learn; ratings ranged from 30% for the importance of knowing about contemporary issues to 54% for data interpretation, as shown in Table 7. These values are approximately 20% lower than those of advanced students who have used the methodology with advanced content. In general, less than 30% of the introductory students perceived themselves as very prepared to fulfill these tasks; the domain in which most introductory students reported adequate preparation was in functioning on multi-disciplinary teams (39% reported ready for this). The 1st and 2nd year students who were enrolled in these classes are expected to show a greater appreciation for the importance of the ABET tasks as they progress through their future courses which future assessments should document. In addition, instructors continually look for ways to help younger students develop a more substantive appreciation of ABET relevant skills.

Table 7
ABET Outcomes

General Effects after use of the AD Board	%* Very Important	%* Very Prepared	% Difference
Ability to apply scientific knowledge to engineering tasks	48	29	19
Ability to design experiments	38	27	11
Ability to interpret data	54	31	23
Ability to design system, component, process to meet desired need	45	26	19
Ability to function effectively on multi-disciplinary team	50	39	11
Ability to communicate effectively as a public speaker	38	29	9
Knowledge of contemporary issues	30	19	11

**Number represents percentage of participants who responded "Very Important" or "Very Prepared" on a 4 point scale (n ranged from 77 to 84)*

The lowest area of preparation (19%) was in knowledge of contemporary issues, the same construct which they reported as least important to the engineering profession. This finding was supported by instructor comments which indicated the need for students to gain global as well as content specific reasons for learning material, noting that the experimental centric approach needed to include not only time to play, to establish "why" something is happening, but time to talk about "why" in terms of the real world context of the problem, "why" a solution is needed, and "how" to look for transfer. Students indicated that these discussions, when they did occur, generally were initiated by the instructor as part of demonstration or in reviewing outcomes in group settings; they noted that these discussions increased their interest advanced coursework and potential research opportunities.

Benefits, Barriers, and Needs Related to Continued Use

Faculty, administrators, students, and local assessment personnel reported multiple benefits, barriers, and needs as use in introductory engineering related classes is continued. Table 8 shows the benefits, barriers and needs from the perspectives of students and faculty/TA.

Table 8
Sustainability-Benefits, Barriers and Needs

	Student Responses	**Faculty/TA Responses**
Benefits	• Increased knowledge about engineering and the profession • Increased interest and "why" we need this material	• Increased hands on opportunities transferred learning • Real world application increased motivation and transferability • Flexibility for use in different contexts

	• Use of and discussions about real-world/practical applications • Allowed opportunity to "play" and "practice" that was not only "fun" but applied	• Allows the faculty member to try out different ways of teaching material • Motivated the faculty to work more with students and TAs
Barriers	• Partnership use had mixed results; got to know other students but one person tends to get most "access" when used in lab • Wanted to take home/opportunity to practice • First time use difficult • Not all students had a laptop/MAC issues • Expensive if have to buy it; not sure if used in later courses	• Application issues with Mac computers • Voltage issues • More examples • Need time to play and develop their own style of use • Need to come up with a check out system so students can take it home/work outside of class
Suggestions for future	• Provide clearer instructions on the AD Board that will work for novice users • More explanation on why need to know/use/goals • Get it at the beginning of the semester • Require individual possession or a semester long checkout • In-class demonstrations on how to use AD Board for projects • Increase in-class use blended with lectures	• Boards available prior to the beginning of the semester, for each student, but still work in pairs, establish some kind of checkout system • Professional development for themselves and colleagues • More modules; more specific use/assessment tie-in • Give the students more time to "play" • Find a way to include this in outreach for K-12 students

Benefits noted by faculty and students included increased hands-on practice and more examples that related to real-world usage. Students perceived that this use lead to greater knowledge about engineering topics and the profession; faculty reported more interest. Faculty also noted revitalized interest in teaching lower level students and a renewed interest in looking at the content as experienced via the eyes of the "new professionals". Both groups noted that the hands-on, experimental approach helped develop skills that would transfer to active practice and learning in future classes. Advanced students who had not had the approach noted that the novice students had practice opportunities that they did not experience and believed these experiences would have better prepared them for their advanced work.

Barriers to use in introductory classes included the need to provide one AD Board per student while finding a way to support collaborative work, the need for time to develop more curriculum and resources that would allow for expanded use on more topics, the lack of introductory materials (videos, instructions, etc.) that would reduce students' anxiety; and equipment specific limitations. Students in introductory engineering classes wanted to increase their involvement in experimental centric practice but wanted more information about how it fit the goals of the course and the degree; they liked the approach, perceived its relevance to the real world, but did not see how it "tied in" to their grade and degree. Faculty noted a key barrier to current successful sustainability was their colleagues' lack of familiarity with the AD Board and experimental centric learning; while the approach was motivating for them, they saw a need to integrate other faculty into the process to include maintaining the current curriculum and making it useful to upper level courses. Lack of AD Boards for other faculty and time for tinkering on course use by non-introductory faculty was seen as a definite barrier to continuation.

Faculty identified several needs to enhance sustainability of use of experimental centric pedagogy in introduction engineering classes. These needs more and less expensive boards that would cover basic concepts; more administrative support and resources for integration of use and transferability to advanced classes; and the need for more blended class formats (classes and labs). Faculty specifically noted the need to find ways to share curricula and assessment tools that can be used to support introductory topics noting great variability across faculty, sections, departments, and institutions. Faculty also wanted more professional development that will allow time for practice and development of experimental approaches. Students wanted more help in initial introductions to the use of the AD Board and more use of experimental pedagogy with help transferring knowledge to the real world and the profession.

Summary

This paper has presented initial pilot findings from a multi-year project that is initiating experimental centric approaches to learning in electrical engineering courses via the use of an AD Board. The specific audience emphasized in the paper reflects participants in introductory engineering and introductory electrical engineering courses. The majority of students are 1st year EE students; the unique audience represents students enrolled in HBCU colleges.

Preliminary data indicate that faculty and students are benefiting from the use of the AD Boards. Students and faculty report increases in constructs reflecting required affective prerequisites to learning including interest in content, motivation to learn, and confidence in ability to learn. Increases in these variables appear to be yielding positive student perceptions of their current knowledge and ability level and these in turn are increasing interest, motivation and confidence to learn. The findings from these pilot studies indicate that an important result of using the AD boards is the influence the pedagogy has on the students' understanding of prerequisites for learning prior to enrolling in advanced classes.

Immediate outcomes, reported by students, and verified by faculty include increased gains in course specific content knowledge, ability to transfer information to new setting, better problem solving, and increased professional characteristics. Again, students in the pilot introduction classes reported outcomes that were similar to those of advanced students.

Use of the approach did not increase student perceptions of selected ABET skills; introductory students continued to report limited importance of and preparation in selected skills and professional practices. This finding is similar to that of general introductory level students.

As the research in this area continues, faculty and students have noted several barriers to use of the process and have suggested potential means of meeting these barriers. These include ensuring that more standardized curriculum modules are piloted, that use of the AD Board as a support for experimental centric learning allow for more independent use both in the classroom and as homework, that use of the approach be integrated in both class and lab settings, and that use be expanded to advanced courses.

Overall, the use of experimental centric approaches to learning and teaching appears to offer a promising method of increasing and enhancing circuits based classes so that future engineers will be better able to meet the needs of a rapidly changing world. Further research is needed on the role of faculty teaching style, specific course content, and long-term achievement outcomes. As this project continues and especially, as students progress from one ECP enhanced course to the next, all of these issues will be addressed. For example, an approach to quantifying the impact on learning of specific course content is being piloted during the spring 2016 term and will be generally implemented in the fall. Standardized, cross-site tools are being developed to much more thoroughly document what has been regularly observed at all partner institutions, but present evidence is still anecdotal.

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