# Experimental Centered Pedagogy Approach to Learning in Engineering: An HBCU's Experience

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## I. Abstract

This paper describes a project of cooperation among thirteen (13) Historically Black Colleges and Universities (HBCU) electrical and computer engineering programs. The intent is to develop an HBCU Engineering Network (HBCU-EngNet) with focus on the development, implementation, and expansion of an Experimental Centric based instructional pedagogy (ECP)

in engineering curricula used in these HBCUs. The ECP is being implemented at the various HBCUs to allow students of varying learning styles the opportunity to learn at their own pace and in their own environments, by providing them an alternative way to acquire technical skills and knowledge both in the classroom and outside.

The paper describes the various learning modules developed by the HBCU networks covering courses in Electrical and Computer Engineering (ECE) first two years curriculum: Introduction to Electrical Engineering, Electric Circuits and Lab, and Electronic Circuits and Lab... these activities were built on the ECP courses that have already been developed, evaluated, and adopted at Howard University and Morgan State University, with an established National Science Foundation (NSF) funded Engineering Research Center (ERC) at Renssalaer Polytechnic Institute (RPI).While these courses were developed using the Mobile studio, the new ECP based learning modules have been developed using the Analog discovery boards. Faculty members of each member HBCU share their labs and class activities through a set of hands-on face-to-face training workshops. The paper also reports on preliminary assessment results of student learning and concludes with the description of lessons learned so far in the project.

## II. Introduction

Engineering students are typically running multiple applications while simultaneously using browsers, instant messaging and search engines on their computers. This modus operandi results in competition for the user's attention and impedes the ability to focus – with the notable exception of the engrossment involved with a computer game. Consequently, the shortened attention spans, lowered tolerance for repetition, and dependence on computers seriously challenges educators to provide information in more dynamic, compelling, thorough, and interactive ways. Furthermore, shortened attention spans impede students from staying engaged and focused in math and science classrooms, resulting in poorer performance and diminished interest in pursuing technical careers. It has been shown that student involvement through hands-on activities and tinkering in and out the classroom can and does help student engage, focus and learn better basic and more advanced engineering concepts. It is also important to note that such student engagement has also been identified as a key factor in remedying the achievement gap among minority populations. Many tools have been developed that use the pedagogy of hand-on based instruction in engineering (see reference attached), A very successful mobile laboratory environment was developed in 2005 based on engineering studio pedagogy for electronics and circuits (Millard, D., & Chouikha, M. (2005, June), Toward The Development Of A Mobile Studio Environment Paper presented at 2005 Annual Conference, Portland, Oregon. https://peer.asee.org/14984) Similarly, in 2009 University of Puerto Rico implemented a hands-on laboratory in power electronics and renewable energy. (Eduardo I. Ortiz-Rivera and Marcel J. Castro-Sitiriche, MIE-2 39th ASEE/IEEE Frontiers in Education Conference, October 18 - 21, 2009, San Antonio, TX.). Such innovations have indeed helped improve the hands-on experience of electronics engineering students. Concurrently, the mobile nature of the instrumentation has enabled the students to interacting with their cohorts and peers at anytime-anywhere. It also eliminated unwieldy laboratory schedules and equipment maintenance. On an even more general level, other research works have shown that the greater the students' active involvement and engagement in academic work in college, the greater their level of knowledge acquisition and general cognitive development. Instructional and programmatic interventions will not only increase a student's active engagement in learning and academic work but also enhance knowledge acquisition and some dimensions of both cognitive and psychosocial change. 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 an 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-based 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 other 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.

## III. The Development of an Infrastructure

The purpose of this paper is to overview of current activities and the resulting outcomes of this project. Data sources included surveys from students at all institutions (pre and post), observations of professional development and student use, and interviews with representatives of all stakeholder groups. In gathering these data, evaluators participated in weekly leadership conference calls, bi-weekly institution conference calls and attended mid-year and end-of-year workshops for all participating institutions. In addition, the evaluation team completed site visits to 9 of the 13 participating institutions, interviewed local stakeholders, and observed use of the mobile devices in the classroom. As part of this process, the evaluators also provided technical assistance to local evaluators and assisted in curriculum/module reviews. A major goal of the project was to develop an infrastructure that would introduce, foster, and expand the use of experiential centered learning in HBCU engineering programs. To meet this goal, the use of hand-held, mobile devices was to be introduced into the curriculum especially that related to electrical engineering: The specific tool selected for this project was the use of an Analog Discovery Board (and other similar devices),The presence of a collaborative, integrated supportive network that includes the sharing of information across all 13 sites, collaboration in developing and implementing common curriculum modules, and sustained engagement amongst the faculty and administrators of the 13 HBCUs: The collaboration is leading to increased sharing of curriculum, shared recruitment and retention strategies, cooperative exploration and use of internal and external resources, and plans for collaborating on future funding and resource allocation. As of June 2015, the collaboration had produced, piloted, and internally distributed 64 curriculum modules and/or labs that focus on experiential hands-on learning using the Analog Discovery board (ADB) in engineering classes: This material represented six major content domains (electrical engineering, computer systems engineering, mechanical engineering, civil engineering, computer science, industrial management engineering) This effort was supported and is being sustained through professional development for faculty offered through midyear and end of year workshops, attended by all sites; Activities included development and sharing of curriculum, sharing of hands-on practice and innovative use, planning for new modes of common assessment, cooperative sharing of resources, and discussions of national and local assessment issues. In addition to these meetings, all institutes participated in twice-monthly teleconferences which provided additional information on innovative practices, shared problem solving, and solution generation. Weekly leadership meetings were used to plan for these sessions and to develop means of assisting local site implementation. The development of a shared google website that offers a portal for curriculum, recorded meeting presentations, innovative practices, and common solutions.

## IV. Implementation: Participants, Settings, and Perceptions of Use

In Year One of the project, the focus was on developing infrastructure and providing professional development to local staff. In Year Two, the major focus of the first term was on piloting the use of AD Boards at the HBCU sites. The goal of the second term was to refine and replicate use while beginning expansion to broader areas of course content and teaching/learning contexts. Students using the ADB at these sites had limited experience with the device and limited prior experience with experiential engineering: across the institutions, while approximately 88% had prior experiences with traditional instruments in lab settings, 59% had no experience with traditional instruments as part of in-class instruction, and 72% never used a mobile device[i]. The developed curriculum materials are being piloted in a variety of *instructional settings* including classrooms, labs, practicum experiences, and a combination of graded and non-graded experiences. Over 250 students were offered experiential engineering modules in the Fall of 2014, almost 500 in the Spring of 2015, and an additional 500 in the Fall of 2015. (See Appendix Tables 1 and 2 for a more detailed description of students.) It is anticipated, that by the end of the planned grant over 2200 students enrolled in HBCUs will have had the opportunity to participate in experientially based learning using the ADBs as a support system.

The AD Boards are being integrated into a variety of *instructional content* including introductory classes in engineering and electrical engineering (EE), classes emphasizing what is traditionally known as Circuits I and II, Systems, Logic, Mechanical Engineering, and Senior Design. All institutions have met their goal of implementing the material into two classes in Year Two and over half have introduced the material in to 3 or 4 classes (Year Three goal).
The *instructional audience* has expanded in Year Two to move beyond EE majors to include minors in EE, other majors in engineering, and at some sites, non-engineering major/minors. (See Appendix Table 2 for an overview; additional breakouts are available in other papers presented at the ASEE conference.)
Students viewed this use as a positive experience[ii]. Three in four students saw their practice with the AD Board as relevant, reflecting course content, and reflecting real practice. Similarly, they approved of the opportunity to practice their content and noted that the hands-on use reflected their learning needs.

**Table 1**
**Student Perceptions of the Process of Use**

| Instruction and Supplementary Materials* | % |
|---|---|
| Use was relevant to my academic area. | 83 |
| The AD board provided opportunities to practice content | 80 |

| | |
|---|---|
| The use of the AD board reflected course content | 79 |
| The use of the ADB reflected real practice. | 76 |
| The time allotted for ADB use was adequate. | 73 |
| The use of ADB suited my learning needs. | 72 |
| **Introduction to the AD Board** | **%** |
| Instructions on ADB use were relevant. | 74 |
| Instructions on ADB use were helpful. | 73 |
| Handouts necessary for ADB use were provided. | 70 |
| The visual aids (e.g. diagrams) used with the ADB were clear and helpful | 69 |

*Number represents percentage of participants who responded "Strongly Agree"/"Agree" on post-survey; n=285

Students did report a need for more introductory materials, videos, and visual aids that would facilitate first time use. This need was also presented by instructors. Several sites have now begun to develop and share videos, introductory curriculum, and practice sites. Several sites also reported that 4th year students are helping with this development. Novice (first time instructors) reported that this difficulty decreased their interest and their students' interest in use of the AD Board and requested help in overcoming this barrier.

Outcomes

Documentation of the impact of use of experientially based learning supported by use of the ADB at the 13 HBCUs is occurring at multiple levels. With the help of independent evaluators, each site is collecting class, use and audience specific data. Variables include key indicators of learning pre-cursors (student differences and affective pre-requisites to learning), course specific outcomes (student and faculty perceptions of knowledge gains and transfer, and where available, concept/content gains via tests, quizzes and products), long term gains as represented by problem solving, interest in continuing in the program, transferability to upper level courses, and increased interest in professional growth, and responses to ABET indicators. The emphasis in year two was to develop a standardized process of documenting immediate gains; year three is emphasizing documentation of content knowledge gains and changes in ABET indicators with the initiation of a plan for documenting retention/major continuation/post graduate work/placement, and continued education.

*Course Specific Outcomes*

Approximately three-fourths of the students reported that use of the AD Board helped them to develop problem solving skills within their content practice, to become more confident in practice, and to think about problems in a graphical/pictorial manner that reflected real-world practice.

Table 2
Student-Reported Growth

| Areas of Growth | %*Fall 2014 |
|---|---|
| Develop skills in problem solving in the content area. | 75 |
| Confidently complete lab assignments. | 74 |
| Think about problems in graphical/pictorial or practical ways. | 74 |
| Recall course content. | 71 |
| Develop interest in the content area. | 71 |
| Become motivated to learn course content. | 71 |
| Improve grades | 70 |
| Learn how AC and DC circuits are used in practical applications. | 69 |

**Number represents percentage of participants who responded "Strongly Agree"/"Agree" on post-survey; n=285*

Initial Long-Term Outcomes

Three in four students also reported that their knowledge in general content had increased and the use of the ADB was an important part of preparing to be an engineer. Most also reported being more motivated to learn the content because of the hands-on use offered by the AD Board. Students noted that use of the AD Board helped them learn to work collaboratively in teams and aided them in learning to transfer knowledge to new content both within and outside of engineering. During interviews, many students noted that they were aided in this transfer due to their ability to pictorially remember their use of the board and their increased confidence because of the "practice" application

**Table 3**
**Initial Long-term Outcomes**

| General Effects after use of the AD Board | % *Fall 2014 |
|---|---|
| My knowledge has increased as a result of use. | 79 |
| The hands-on ADB is important in my preparation as an engineer. | 79 |
| My confidence in the content area has increased because of use. | 75 |
| Using the ADB motivated me to learn the content. | 70 |
| Specific Effects of ADB Use / Transfer of Skills/ Using the ADB helped me to: | |
| Work collaboratively with fellow students. | 78 |
| Apply course content to new problems. | 74 |
| Develop confidence in content area | 74 |
| Transfer knowledge/skills to problems outside the course. | 70 |

*Number represents percentage of participants who responded "Strongly Agree"/"Agree" on post-survey; n=285

Professional Long-term Outcomes: ABET Indicators

As part of the Fall 2014 and Spring 2015 evaluation of the AD Boards, students were asked to address their confidence level on multiple ABET indicators. Students reported changes pre to post that were greater than one standard-error of difference in positive trends for scientific knowledge and design of experiments. No major changes were noted for interpretation of data or for design of a problem. Final post reflections reflected weaknesses in these areas despite the growth: post 37% scientific knowledge; post 39% design of experiment; post 43% interpret data; and post 35% design a problem. It should be noted that the matched data came primarily from introductory/entry/first course-level classes.

No major changes were noted (as assessed by greater than one standard error of measurement) on items related to higher level skills such as communication, functioning on multi-disciplinary teams and general knowledge. Confidence in these areas tended to remain stable or to show a slight decline. Students overall confidence at post, however, was higher in these areas (generally around 50%).

## V. Sustainability

During 2014-15 (Year Two of the project), the evaluators conducted site visits at 9 of the 13 sites. During these site visits, evaluators interviewed faculty, students, administrators, and local collaborators. Three categories of sustainability levels were noted; these included xxxx transition

*At all sites:* The staff commitment to use was high: All projects had at least one actively involved faculty member, most had new faculty who were joining the program in the Fall of 2015 as part of department integration and growth, and all sites met the goal of at least 2 classes participating in use. Administrators at all sites were supportive of the project, aware of its potential, knowledgeable of faculty involvement, and involved in providing resources. Plans were in process for expansion to Year Three goals and training and resources were being set aside for this use.

*At selected sites:* Advanced and unplanned use of the AD Board included: Use in 3-4 classes, additional purchasing of equipment, release time for training of new faculty, and inclusion of upper-level students in implementation, training, and practice. Use of the board expanded via students, with industry partners, as part of projects, internships, and presentations. Use with non-EE majors included business and fine arts majors, and sharing of informal lessons learned by faculty and students was facilitated.

*Innovative uses*: Mandatory curriculum changes for first year students; adaptation to systems and logic classes; collaborative use across classes/content; student-faculty mentoring with students teaching faculty, and exemplary outreach to community colleges, K-12 and professional visits

## VI. Benefits and Needs

Faculty, administrators, students, and local assessment personnel reported multiple benefits and needs as the project is continued. A summary of these responses are provided in Table 4.

**Table 4**
**Sustainability-Benefits, Barriers and Needs**

| | **Student Responses** | **Faculty/TA Responses** |
|---|---|---|
| **Benefits** | Increased knowledge about circuits<br>Provided good visual representations<br>Facilitated hands-on experience<br>Visualization of real-world/practical applications | Increased hands on opportunities transferred learning<br>Real world application<br>Flexibility for use in different contexts |
| **Barriers** | Partnership use<br>Wanted to take home/opportunity to practice<br>First time use difficult<br>Not all students had a laptop/MAC issues | Came late or not enough boards<br>Application issues with Mac computers Voltage issues |
| **Suggestions for future** | Provide clearer instructions on the ADB<br>Require by at least sophomore year or a semester long checkout<br>In-class demonstrations on how to use ADB for projects<br>Increase in-class use blended with lectures<br>Make it a part of the class | Boards available prior to the beginning of the semester<br>Help in involving more faculty and content<br>Professional development for themselves and colleagues<br>More devices for faculty and TAs<br>Outreach opportunities<br>Internal recognition for Faculty involvement |

*Benefits:* increased knowledge and greater creativity resulting from the hands-on use; increased confidence; and more real-world knowledge as theory is tied to practice.

*Barriers:* need for one AD Board per student (not shared), the need for full semester use and take home use; the need for check out systems that allow for more in-depth use; lack of introductory materials (videos, instructions, etc.); and support for faculty involvement from Dean to President level.

*Future needs:* more boards, internal and external professional rewards for involvement from the project leadership; refined curricula to share, assessment tools; more time for practice provided to faculty and more opportunities for hands-on sharing of curriculum.

## VII. Dissemination of Process, Products, and Outcomes

*Internal Dissemination:* All sites are actively engaged in disseminating the theory and practice of hands-on experiential learning within their local departments and schools. Additional faculty is being introduced to the theory and faculty is cross-training while upper level students and graduate students are also being included in the process. In addition, some sites have reached across department lines and, with additional resources, would like to include faculty in supporting areas (such as physics) if possible. Some sites have made formal presentations to their departmental colleagues and to other internal sites. While not available on the google site, these presentations could be shared for future use. One site has made experiential hands-on use a mandatory part of the curriculum and other sites are reviewing this process.

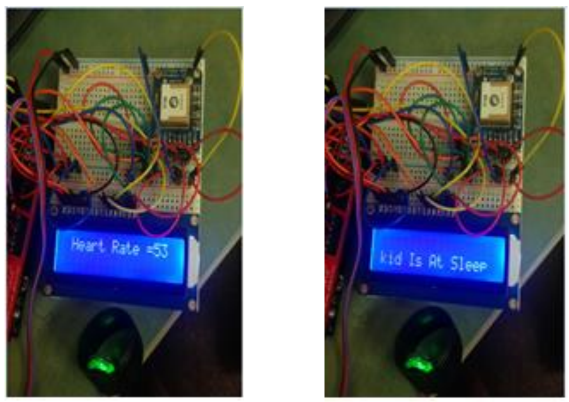
*External Dissemination:* The project team has presented, is in the process of presenting, and is proposing paper and oral reviews of the project's process and outcome at multiple national and international venues. A listing of these events is available in the project administrator report. Multiple papers are being presented at the 2016 ASEE Conference[iii]. Several sites have requested site-specific data for use with professional publications that will explore their unique approach to use. In several cases, the local assessment person is exploring additional educational/instructional theories in light of the project and its use. Several project staff/leadership team members are disseminating the materials (process and products) to other grant/project groups including different ethnic groups, international domains, and under-developed sites. Project staff is also disseminating the process and products to K-12 settings and to local community colleges as a means of improving experiences of under-funded disadvantaged and feeder schools.

*Future Collaboration:* Participants of the 13 sites have recognized the value of a larger collaboration and are actively engaged in seeking additional funding for resources and outreach. Participants within the 13 sites have recognized common problems in recruitment, retention, and graduate placement and are addressing common issues across their sites. Participants within and outside of the collaboration have observed a need for more involvement of industry at the 13 sites and are sharing their outreach efforts and their placement efforts.

Example:
The following example shows an instance where students at the University of Maryland Eastern Shore are using the kit and the ADB (without the input of instructor.
0 illustrates a senior design project example, exoskeleton 'B.T. Suit', which integrated many devices such as servos, cameras, microcomputer, various sensors and etc. By the use of the kit, student can test and operate on-site all functions as they need it and when they needed which is much more convenient than using the traditional lab setting. Fig. 1 illustrates another senior design project, a wearable device 'Communicare' in this case the ADB kit is used to mimic pulses in different rates to test the cardiac analytic algorithm that the students developed.

(a) (b)

a) The project suit, and b) demonstration of firethrower.




(a) (b)

Fig. 1. Senior design project: wearable device ‘Communicare’.

## VIII, Summary

As the project reaches the midpoint of year three, it is meeting its goals and is actively involved in planning for expansion beyond the grant timeframe. The program has been successfully piloted in all 13 sites; at some sites implementation is ahead of schedule; and at no site is implementation behind schedule. The leadership team is actively involved in guiding the project; the weekly conferences are fundamental to monitoring the progress of the project and in helping local sites solve problems. The required twice-monthly all-site conferences are greatly beneficial in building the community and collegiality amongst the sites. This project may be exemplary in this regard and could serve as a model of shared decision-making and dissemination.

Preliminary data indicate that faculty and students are benefiting from the use of the AD Boards. As collection of affective data and content surveys continue in Year Three, and as the availability of matched data sets becomes available, outcomes can be more defined. Several sites are now in the process of more exacting documentation of use that also will allow for further refinement of approaches.

The project is actively moving toward current maintenance and is seeking funding internally and externally for long term sustainability. The staff is involved in dissemination and is working toward gathering even more scientific evidence of success. In summation, the project has successfully met Year Two goals, has identified barriers and challenges that are now being addressed in Year Three, and is planning for additional expansion of resources.

Appendix

Appendix Table 1
Student Demographics (based on Fall 2014 students)

| Gender | Gender % |
|---|---|
| Male | 74 |
| Female | 26 |
| **Ethnicity** | **Ethnicity %** |
| Black | 79 |
| Asian | 6 |
| Multi-racial | 5 |
| White | 5 |
| Hispanic | 4 |
| **English Primary Language** | **Language %** |
| Yes | 86 |
| No | 14 |

Appendix Table 2
Student Status (based on Fall 2014 students)

| Discipline of Study | Major % |
|---|---|
| Electrical Engineering | 75 |
| Computer Science | 18 |
| Mechanical Engineering | 3 |
| Other** | 4 |
| **Degree Progress** | **Degree %** |
| Undergraduate year 3-4 | 72 |
| Undergraduate year 1-2 | 28 |
| Graduate/5th year | 1 |

i Based on pre data collected in the Fall of 2014 by project evaluators.
ii Data presented in the following tables are based on Fall 2014 responses to evaluation surveys. Additional data for spring 2015 are available; fall 2015 data are in the process of being collected and analyzed.
iii Following is a listing of papers available for download review and attendance.

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28. Jiang, X., & Young, L., & Sarin, S. (2005, June), *Assessment of the NC Lsamp Project: A Longitudinal Study* Paper presented at 2005 Annual Conference, Portland, and Oregon.

29. Mackie, C., & Jangha, S., & Haley, R. (2003, June), *Focus: The Evolution Of A Recruiting Initiative For African American Graduate Students At Georgia Institute Of Technology* Paper presented at 2003 Annual Conference, Nashville, Tennessee.

30. Fleming, L. N., & Smith, K. C., & Williams, D. G., & Bliss, L. B. (2013, June), *Engineering Identity of Black and Hispanic Undergraduates: The Impact of Minority Serving Institutions* Paper presented at 2013 ASEE Annual Conference, Atlanta, Georgia.

31. Connor, K. A., & Ferri, B. H., & Meehan, K. (2013, June), *Models of Mobile Hands-On STEM Education* Paper presented at 2013 ASEE Annual Conference, Atlanta, Georgia.

32. Millard, D., & Connor, K., & Coutermarsh, J. (2006, June), *Re Engaging Engineering Students in Hands on Education*Paper presented at 2006 Annual Conference & Exposition, Chicago, Illinois.

33. Connor, K. A., & Newman, D. L., & Deyoe, M. M. (2014, June), *flipping a Classroom: A Continual Process of Refinement* Paper presented at 2014 ASEE Annual Conference, Indianapolis, Indiana.

34. Robertson, J. M., & Meehan, K., & Bowman, R. J., & Connor, K. A., & Mercer, D. A. (2013, June), *Exploiting a Disruptive Technology to Actively Engage Students in the Learning Process* Paper presented at 2013 ASEE Annual Conference, Atlanta, Georgia.

35. Morales, J. C., & Astatke, Y., & Connor, K. A., & Prince, M. J., & Vergara-Laurens, I., & Ruales Ortega, M. C. (2015, June), *A Plan to Diffuse Mobile Hands-On Teaching and Learning in Puerto Rico* Paper presented at 2015 ASEE Annual Conference and Exposition, Seattle, Washington

36. Connor, K. A., & Scott, C. J., & Chouikha, M. F., & Wilson, A. M., & Anderson, A., & Astatke, Y., & Berry, F. C., & Newman, D., & O'Rourke, J. E., & Little, T. D., & Millard, D. L. (2011, June), *Multi-Institutional Development of Mobile Studio Based Education and Outreach* Paper presented at 2011 Annual Conference & Exposition, Vancouver, BC.

37. Connor, K. A., & Astatke, Y., & Kim, C. J., & Eldek, A. A., & Majlesein, H. R., & Andrei, P., & Attia, J. O., & Gullie, K. A., & Graves, C. A., & Osareh, A. R. (2015, June), *Simultaneous Implementation of Experimental Centric Pedagogy in 13 ECE Programs* Paper presented at 2015 ASEE Annual Conference and Exposition, Seattle, Washington.

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