# Growing Experimental Centric Learning: The Role of Setting and Instructional Use in Building Student Outcomes

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## Abstract

The need for experimental centric learning in engineering education has been a major area of discussion and innovation for the last decade. Research has proven that, in general, the impact on student learning is beneficial. Little literature is available, however, on the impact of instructional use and learning setting when this approach is used. This paper presents preliminary results from a two year collaboration of 13 HBCU electrical and computer engineering (ECE) programs working collaboratively on the development, implementation, and expansion of Experimental Centric based instructional Pedagogy (ECP) in essentially all engineering courses in which circuits and electronics play significant role. As of June 2015, the 13 participating institutions have produced, piloted, and internally distributed 64 curriculum modules and/or labs. The purpose of this paper is to provide preliminary results of an investigation of the relationship of learning setting and instructional use of experimental centric learning, especially for students of color. Learning settings studied include: 1) *traditional classrooms*, 2) *lab settings* and 3) *homework.* Variations by instructional use included: 1) *instructor demonstration,* 2) *cooperative* and 3) *independent* student use. Student outcomes reflect gains in: 1) *pre-requisites* to learning; 2) immediate *short-term* learning; 3) *long-term and transferable* outcomes and 4) selected *ABET* characteristics (importance and preparedness). Findings indicate that both setting and instructional use do influence selected outcomes and that prior identified patterns of instructor development when incorporating new practices are upheld. The study begins a conversation on the implications of these influences and the need for further research on how students, faculty, and instructional practices change when using experimental centric learning.

## Introduction

Reform literature[1] related to learning in 21st Century higher education has called for a change in how students interact with new knowledge. Today's undergraduate students come from a K-12 environment that is based on integrated, constructivist instructional practices. These practices are fostered by instructional methods that allow students to learn through hands-on practices, experiential learning, and group work. Gaining new skills, abilities and knowledge is not a passive or stagnant event but is perceived to be an active, engaged process that relates new information to past experiences[2]. This is especially true in the STEM domain; Howes et al[3] note that an important developments for STEM instruction is not only the inclusion of problem solving and application/modeling skills, but, even more importantly, is the now common expectation that these processes will be present. 21st Century students entering STEM professional preparation expect that they will be involved in hands-on investigations and intellectual challenges that will result in deeper understanding of concepts making them more immediately prepared to work on real world problems.

Current research[4,5,6,7] indicates that technology can be used to foster the movement of theory to practice especially when combined with experimental centric practices. Engineering education has built on this knowledge base to develop innovative hands on approaches to learning that meet the needs of students and faculty. Several research programs[8,9,10,11,12] have investigated and found that the use of mobile studio classrooms, mobile platforms, and other hands-on devices impact students' interest, immediate knowledge gains, retention, and long-term transfer; for instance, Connor and colleagues have found that hands-on learning via mobile studio platforms meets the needs of students with diverse learning styles, demographics, and academic backgrounds. This method, based on the concept of experimental centric learning integrates problem based activities and constructivist-based instruction through the use of an Analog Discovery Board (ADB) that is designed to replace larger laboratory equipment. The Mobile Studio/ADB design allows students more freedom than old-fashioned labs which are limited by time and space. Not only can the ADB be integrated into classroom and lab settings, it also has the potential to allow for practice outside the class where students can interact with peers, practice their use of knowledge, and solve real-life problems while rehearsing skills. In studies reviewing outcomes of this use, these practices have been found to impact students' direct learning as well as future industry needs[10].

These studies, however, are limited in two ways. First, the majority of these studies are based on audiences that reflect "typical" engineering classes composed mostly of White, non-minority students. As we know, there is a high need to recruit, retain, and place minority students in the field of engineering, especially electrical engineering. To investigate this need, a consortium of EE programs situated in HBCU has begun to pilot the use of experimental centric engineering education supported by the ADB. Results of these studies are beginning to show success; specific outcomes are being presented at other sessions of this conference. The second limitation of current ADB based experimental centric research reflects the lack of literature showing its transferability to different instructional modes and settings. While Newman, Deyoe, Connor and colleagues[13,14,15] have demonstrated that the mobile studio /ADB platform is transferable across different types of instructors, and Newman and Connor et al[16,17] have shown that it works well in flipped classrooms, there is limited evidence about usefulness in different instructional settings and in different student roles. Equally important, this limited evidence does not examine the impact of varied uses for minority students. As a result of this lack of information the consortium of HBCUs with electrical engineering departments is now expanding their multi-year study to examine the impact of different types of instructional and student roles.

**Purpose of the Paper:**

The purpose of this paper is to provide preliminary results of an investigation of the relationship of learning setting and instructional use of the Analog Discovery Board (ADB) on potential student outcomes. Learning settings studied in this paper include: 1) *traditional classrooms* (e.g. instructor centered, emphasis on transmittal of theory with limited integration of the ADB and experimental centric learning introduced for students to practice new concepts); 2) *lab settings* (e.g., student- centered, emphasis placed on practicing and discovering concepts introduced via separate lecture based formats; lab instructors and lecture instructors were not always the same); and 3) *homework* (e.g. project and problem-solving work assigned to students as extensions of either traditional or lab based activities; sometimes for credit, sometimes for extra credit, sometimes volunteer activity). Variations by instructional use included: 1) *instructor demonstration* (e.g., faculty active; student passive, instructor usually at the front of the classroom); 2) *cooperative* (e.g. student-student dyad or triad collaboration working on a specific assignment in classroom and in lab settings); and 3) *independent* (e.g. autonomous student use;

assigned or volunteer). These six variables, assessed via student and instructor feedback, served as the primary independent predictors. Results of outcome concepts include self-reported gains in: 1) *pre-requisites* to learning (e.g. perceptions of importance of and interest in material/concepts); 2) immediate *short-term* learning (e.g. recall, improved grades, use in specific context/content); 3) *long-term and transferable* outcomes (e.g. problem-solving, working collaboratively, communication, etc.).

**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 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 Experimental Centric Learning pedagogical approach promotes portable student tools to verify concepts, experiment anywhere, and experiment anytime as one would do in a traditional laboratory setup

The goal of the project is to increase the number of highly qualified and prepared African American engineers, and for 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 tasked with using portable hands-on hardware coupled with a student-centered, experimental 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 AD Boards are USB powered and interface with computers through a free WaveForms™ software. The capabilities of the AD Boards include: a 5V DC power supply, a 2-channel oscilloscope, 2 channel waveform generator, 16-channel logic analyzer, 16-channel digital pattern generator, spectrum analyzer, network analyzer, voltmeter, and digital I/O.[18] The AD Boards and supporting curriculum modules were piloted at multiple instructional/degree granting HBCU setting in 2013-2015. The findings from this paper represented data from 623 students across 13 institutions, 5 terms, and 32 separate course sequence numbers (e.g. introduction to electrical engineering, electric circuits, and electronic circuits). Additional data include observations and interviews with faculty, administrators, and students at nine HBCU sites.

Presented in Table 1 are the student demographics. The majority of students were male (77%); 75% self-reported ethnicity as Black, 5% as Hispanic, and 5% 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. Overall, 36% of the students were in their first or second year of undergraduate education, 58% were in years 3 or 4, and 7% were 5$^{th}$ year enrollees.

Most of the students, 66% were majoring in electrical engineering; 20% reported majors in computer science or mechanical engineering. The remaining students generally reported majors related to other STEM majors for which the course served as an elective or to fulfill a minor requirement. Approximately 43% of the data represent responses from students enrolled in circuits related courses, 14% represent enrollees in introductory classes, and 42% were gathered from students enrolled in a variety of advanced and supporting electrical engineering courses (e.g. systems, logic, design).

**Table 1**
**Student Demographics (n=623*)**

| **Gender** | **Gender %** | **Discipline of Study** | **Major %** |
|---|---|---|---|
| Male | 77 | Electrical Engineering | 66 |
| Female | 23 | Computer Science | 15 |
| **Ethnicity** | **Ethnicity %** | Mechanical Engineering | 5 |
| Black | 75 | Other** | 14 |
| Asian | 7 | **Degree Progress** | **Degree %** |
| Multi-racial | 5 | 1st year | 11 |
| White | 7 | 2nd year | 25 |
| Hispanic | 5 | 3rd year | 38 |
| **English Primary Language** | **Language %** | 4th year | 20 |
| Yes | 85 | Graduate/5th year | 7 |
| No | 15 | | |

*student data represent 623 post surveys
**Students self-reported majors in Industrial Engineering (4%), Business (3%) and other Engineering and STEM related majors (7%)

## General Overview of Use

Median use of the ADB was 2-3 times a semester in the classroom, 3-5 times a semester in the lab setting, and as homework 3-5 times. (Range of values was from 0 to 15). In approximately two out of three settings there was some overlap with uses. Instructors noted, and evaluators verified through observations, that use of the ADB and experimental techniques tended to occur first in lab settings or lab courses, frequently as a replacement or supplement to existing curriculum. Those instructors who moved it into lab settings initially used it in a traditional method and did not use experimental centric approaches for at least one semester and in some cases two semesters. The role of the TA was key in the lab setting; if the TA did not know how to use the ADB, its use was limited; similarly, if the TA did not know how to do experimental centric teaching, it did not occur. If the lab TA did know how to use the ADB and was familiar with experimental centered/constructivist learning, but the instructor was not, it generally was the TA who took the lead and showed selected groups of students how to use the ADB and involved selected groups in experimental centric learning.

Secondary use, after integration into labs, reflected integration into classroom learning. Again, the role, experience, and comfort-level of the instructor and the support students were key with moving use of the ADB beyond teacher-centered demonstrations to more hands-on use that finally resulted in experimental centric learning and real-world problem solving activities. Those instructors who did move use of hands-on learning from the lab into their classrooms tended to start with instructor based demonstrations, and as they became more comfortable and confident in their own use, increased direct exploratory use and more student-centered assignments. In some classes taught by novice instructors, students (either within the class or advanced) were key to introduction of the ADB and transfer to experimental use.

When queried during interviews, students wanted independent learning both in lab and in homework settings. The finding reflecting students' desire and need for more opportunities to "tinker" and "explore" was reinforced by TAs and more experienced faculty activities and comments. These participants noted the need for and resulting benefits of each student having their own ADB which could be taken and used for the entire semester both in and out of class. Novice faculty did not see the need for independent, continuous student access to the ADB and were more focused on the administrative issues related to resource management than the benefits of use; most administrators and novice faculty expressed concerns over student breakage and monitoring return after use and hence limited use outside of supervised lab settings. In these limited use settings, it was noted that frequently one student did all the work and 3 or 4 students would "watch"; consequently limited benefits were reported.

## Relationship of Type and Setting of Use with Learning Outcomes

Overall these pilot studies indicate that use of experimental centric learning supported by the ABD is related to increased pre-requisites of learning, immediate learning outcomes, and selected indicators of long-term learning as well as selected ABET indicators. Triangulation of student, faculty/TA, and evaluator observations indicate several key findings. Presented in Table 2 is an overall summary of findings for the student outcomes by type of setting, and type of use. Offered in Tables 3 and 4 are more in-depth examinations of findings for type of setting and type of use. Presented in Table 5 is a more extensive overview of ABET related perceptions.

**Table 2**
**Student Outcomes by Type of Setting and Type of Use**

| | | Type of Setting | | | | | Type of Use | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Perceived Changes | Traditional Class | Studio Class | Add on Lab | Integrated Into Lab | Homework | Instructor Demo Tech | Instructor Demo Problem | Peer | Independent |
| Pre-requisite to Learning | Develop interest in the content area. | | ++ | ++ | ++ | | + | ++ | | ++ |
| Pre-requisite to Learning | My confidence in the content area increased because of use. | | | + | ++ | +++ | | + | ++ | +++ |
| Pre-requisite to Learning | Using the ADB motivated me to learn the content. | | | | ++ | +++ | | ++ | ++ | +++ |
| Pre-requisite to Learning | The hands-on ADB is important in my preparation as engineer. | | | | | ++ | | +++ | | |
| | | | | | | | | | | |
| Immediate Learning | Develop skills in problem solving in content area. | | | | ++ | ++ | | | | +++ |
| Immediate Learning | Think about problems in graphical/pictorial/ practical ways. | + | ++ | + | ++ | +++ | | | | +++ |
| Immediate Learning | Learn how AC and DC circuits used/practical applications. | + | ++ | + | ++ | +++ | | ++ | | |
| Immediate Learning | Recall course content. | + | ++ | + | ++ | +++ | | | | +++ |
| Immediate Learning | Improve grades | + | ++ | + | ++ | +++ | | + | | |
| Immediate Learning | My knowledge increased as a result of use. | | + | + | ++ | ++ | | + | ++ | +++ |
| | | | | | | | | | | |
| Long-term Transferrable | Enhanced my professional abilities | | | | | | | | | ++ |
| Long-term Transferrable | Work collaboratively with fellow students. | | | | | ++ | | | ++ | |
| Long-term Transferrable | Transfer knowledge/skills to problems outside the course | | ++ | | | ++ | | ++ | | |
| Long-term Transferrable | Develop different ways of solving problems | | ++ | | + | ++ | | ++ | ++ | |
| Long-term Transferrable | Apply course content to new problems. | + | ++ | | + | | | ++ | | |
| Long-term Transferrable | Develop attitudes of self-direction and self-responsibility | | | | | ++ | | | ++ | ++ |
| | | | | | | | | | | |
| ABET Indicators | Ability to apply scientific knowledge to engineering tasks | | | | | + | | | | |
| ABET Indicators | Ability to design experiments | | | | | | | + | | |
| ABET Indicators | Ability to interpret data | | | | | | | + | | |
| ABET Indicators | Ability to design system, component, process to meet need | | | | | | | + | | |
| ABET Indicators | Ability to function effectively on multi-disciplinary team | | | | | + | | | | |
| ABET Indicators | Ability to communicate effectively as a public speaker | | | | | | | | | + |
| ABET Indicators | Knowledge of contemporary issues | | | | | | | + | | |

*+ indicates a positive low correlation; ++ a positive moderate correlation, +++ a positive high correction*

***The Impact of Setting*.**

Analysis of the data indicated the presence of 5 types of settings, rather than the three that were expected. These included use in a *traditional classroom* (the instructor used lectures and exploration/hands-on work took place in lab setting, frequently with a different instructor); *studio classrooms* (instructor lectures were followed by direct implementation within the classroom with the same instructor working with students); *comparative labs* (students worked with the ADB as part of lab, outside direct instruction, use was an "add-on" or a comparison with traditional equipment); *integrated labs* (students worked with the ADB as part of lab, outside direct instruction, sometimes with a different instructor, but use was part of the required coursework and supplemented/supplanted traditional equipment), and *homework* (students were assigned tasks on the ADB that were to be accomplished outside either classroom or lab; some of these exercise were part of the traditional grade, some were volunteer, and others were for extra credit.) Each of these approaches were found to have a potential impact on learning outcomes. Following is a brief description of impact for each setting. A summary of the relationships of these types of settings with student outcomes is presented in Table 3.

*Traditional classrooms:* Examination of the data indicates that use of the ADB only in a traditional classroom has limited, short term impact and only on specific indicators of immediate learning. In these settings, where the instructor at most demonstrates some use, or references possible, to later lab assignments in which the ADB might be used, but in which theory and practice are separated, students tended to use the ADB as a cue for immediate recall of content and perceived the ADB as a graphical/visual reminder of content that might be required to improve their course grade. Little or no practical or transferrable knowledge or use was recognized, nor was there an increase in content interest, motivation or confidence in knowledge or professional ability. The ADB, in the traditional classroom, with no hands-on practice, was perceived by the students to be just another part of the lecture (e.g. "I have it in my notes because it was part of the class and might be on the test, but it wasn't" and "We had it, I don't know why, but it was OK.")

*Addition to Traditional Labs:* When the ADB was introduced into lab settings, not as a requirement, but as a hands-on comparison tool to traditional equipment, similar findings were found to those demonstrated above. Students in these lab settings indicated that when they used both traditional equipment and the ADB, and as part of the exercise, compared and discussed difference in results, they had slightly better recall of course content and specific applications, and that use of the ADB helped to recall/think in pictorial or visual ways. These students also noted a slight increase in self-perceived knowledge and confidence in their knowledge and a moderate increase in interest. Practical, comparable, hands-on use appears to have some impact on immediate learning, while beginning to foster confidence and interest in learning and content.

*Integrated Labs:* Truly integrated use of the ADB into hands-on practice via lab settings was found to be moderately related to learning outcomes at all three levels. When lab use was required, frequent, part of assignments, but indirectly tied to theory, students reported greater increases in all areas of immediate learning (specific content, overall recall, improved knowledge and better grades). These students also reported an impact on overall knowledge and problem solving skills. Low level changes in long term transferable skills also were noted in general problem solving and in applying course content to new areas. Concurrently, pre-requisites to this learning and future learning were noted to increase; this included growth in interest, confidence in learning/content, and motivation to learn the content.

**Table 3**
**Student Outcomes by Type of Setting and Type of Use**

| | | **Type of Use** | | | | |
|---|---|---|---|---|---|---|
| | **Perceived Changes** | **Tradit Class** | **Add on Lab** | **Integr into Lab** | **Studio Class** | **Home work** |
| Pre-requisite to Learning | Develop interest in the content area. | | ++ | ++ | ++ | |
| Pre-requisite to Learning | My confidence in the content area increased because of use. | | + | ++ | | +++ |
| Pre-requisite to Learning | Using the ADB motivated me to learn the content. | | | ++ | | +++ |
| Pre-requisite to Learning | The hands-on ADB is important in my preparation as engineer. | | | | | ++ |
| | | | | | | |
| Immediate Learning | Develop skills in problem solving in content area. | | | ++ | | ++ |
| Immediate Learning | Think about problems in graphical/pictorial/ practical ways. | + | + | ++ | ++ | +++ |
| Immediate Learning | Learn how AC and DC circuits used/practical applications. | + | + | ++ | ++ | +++ |
| Immediate Learning | Recall course content. | + | + | ++ | ++ | +++ |
| Immediate Learning | Improve grades | + | + | ++ | ++ | +++ |
| Immediate Learning | My knowledge increased as a result of use. | | + | ++ | + | ++ |
| | | | | | | |
| Long-term Transferrable | Enhanced my professional abilities | | | | | |
| Long-term Transferrable | Work collaboratively with fellow students. | | | | | ++ |
| Long-term Transferrable | Transfer knowledge/skills to problems outside the course | | | | ++ | ++ |
| Long-term Transferrable | Develop different ways of solving problems | | | + | ++ | ++ |
| Long-term Transferrable | Apply course content to new problems. | + | | + | ++ | |
| Long-term Transferrable | Develop attitudes of self-direction and self-responsibility | | | | | ++ |

*+ indicates a positive low correlation; ++ a positive moderate correlation, +++ a positive high correction*

*Studio Classrooms:* Use of the ADB accompanying experimental centric learning had a moderate relationship with indicators of learning when used in a studio classroom. In these settings, when overviews of theory and practice took place concurrently with the same instructor, in the same settings, impact was noted for immediate learning, as well as long term transferable earning. Within, or for that specific class, moderate gains were noted in recall of content, specific content domains, and subsequently improved grades. Students reported the ADB experience was a help in thinking pictorially and reported greater motivation to learn as well as increased knowledge. Immediate concurrent theory and practice integration via the use of the ADB, had its greatest impact, however, on the development of long term transferrable problem solving skills. This included transfer of problem solving to new areas within the course as well as to problems outside the course. Students noted a growing repertoire of different ways to solve problems. Several students provided direct examples of this transfer, noting use in other assignments, other classes, and in their personal life.

*Homework:* The greatest impact of the ADB was found when it was used as a truly mobile device. In this settings, when used as part of a homework assignment, outside the lab or classroom, in a student-centered environment, high relationships were found for all levels of learning. Changes were noted in pre-requisites for learning (confidence, motivation, and importance in preparation). The more students used the ADB outside the traditional settings, and in environments where they could play, tinker, or compare notes, whether required or voluntarily, the more they learned about course content, the more they recalled that information, the more they developed skills in visualization, and the more they developed and used problem solving skills for that content. Outside of class, hands-on use, allowing for application and practice of theory, in their time, on their terms, also increased their long-term transferrable skills; this included skills related to content as well as their future professional needs. These included transferrable problem solving skills similar to those noted for the studio classroom but also included the ability to work collaborative and to develop self-direction/self-responsibility. When the ADB "went home" on a regular basis, knowledge became more personal, more relevant, and more ingrained.

***The Impact of Type of Use.***

Type of use (e.g., interactions with others) also was found to influence learning outcomes. Analysis of data searched for three types of interactions: *instructor demonstration* (with the student being passively involved), *peer interactions* (collaborative or cooperative work with another student) and *independent use* (the student worked independent of other students with minimal faculty guidance). A review of the data, however, indicated that instructor demonstration consisted of two very different formats that had a major impact on reported learning. The first type of *instructor demonstration (technology)* was used to introduce the technology of the ADB to the students and focused on how to manipulate the device for required uses. Specific tasks were demonstrated and students either watched the results or were given assignments that replicated this use. The second type of *instructor demonstration (problem solving)* was used by the instructor as either a form of advanced organizer to introduce specific topics and to show what students would be able to do when they had learned a specific content domain or as a summary exploration tool in which the instructor indicated more advanced uses. In both of these situations, the instructors utilized real world professional problems and suggested alternate methods of developing solutions. In these situations, the student was still in a passive observant mode with no direct hands-on experience as part of the immediate process. These two types of use (instructor demonstration-technology and instructor-demonstration) were identified as well as the hypothesized supporters of peer-based and independent use. Each of the four were found to support learning in different ways. A summary of findings by type of use is presented in Table 4.

*Instructor Demonstration-Problem-solving:* Faculty use that focused on problem solving was found to help increase pre-requisites to learning interest and motivations to learn; immediate learning outcomes (ability to complete labs, confidence in learning about AC/DC and in improving the course grade) and in learning problem solving skills and knowing how to apply their knowledge to new problems. Students and faculty also noted greater ability of students to transfer their problem solving and more confidence in trying to transfer, outside the course.

*Instructor Demonstration-Technical*: Instructor uses that focused only on demonstrating how to set up and/or learn the technical skills of ADB use, or in some cases, consisted of just a demonstration with no subsequent assignment, were found to not be beneficial in helping foster immediate learning or long-term transfer. Students did note that these demonstrations reduced frustration with use of the equipment and helped them to learn to use the device "faster" and "better" if there was a follow-up assignment. If, however, these demonstrations did not advance to real world use, students reported that they were "exercises in learning to use [non-important] equipment" but did not report any added value to the course content.

**Table 4**
**Student Outcomes by Type of Setting and Type of Use**

| | | Type of Use | | | |
|---|---|---|---|---|---|
| | **Perceived Changes** | **Instr Demo** Tech | **Instr Demo Prob Solv** | **Peer** | **Indep** |
| Pre-requisite to Learning | Develop interest in the content area. | + | ++ | | ++ |
| Pre-requisite to Learning | My confidence in the content area increased because of use. | | + | ++ | +++ |
| Pre-requisite to Learning | Using the ADB motivated me to learn the content. | | ++ | ++ | +++ |
| Pre-requisite to Learning | The hands-on ADB is important in my preparation as engineer. | | +++ | | |
| | | | | | |
| Immediate Learning | Develop skills in problem solving in content area. | | | | +++ |
| Immediate Learning | Think about problems in graphical/pictorial/ practical ways. | | | | +++ |
| Immediate Learning | Learn how AC and DC circuits used/practical applications. | | ++ | | |
| Immediate Learning | Recall course content. | | | | +++ |
| Immediate Learning | Improve grades | | + | | |
| Immediate Learning | My knowledge increased as a result of use. | | + | ++ | +++ |
| | | | | | |
| Long-term Transferrable | Enhanced my professional abilities | | | | ++ |
| Long-term Transferrable | Work collaboratively with fellow students. | | | ++ | |
| Long-term Transferrable | Transfer knowledge/skills to problems outside the course | | ++ | | |
| Long-term Transferrable | Develop different ways of solving problems | | ++ | ++ | |
| Long-term Transferrable | Apply course content to new problems. | | ++ | | |
| Long-term Transferrable | Develop attitudes of self-direction and self-responsibility | | | ++ | ++ |

*+ indicates a positive low correlation; ++ a positive moderate correlation, +++ a positive high correction*

*Peer:* Peer use, which took place in both classroom types and both lab types, were noted by faculty and students to minimally help participants to learn to work collaboratively, to be more confident in developing different solutions, to gain some sense of self-direction and responsibility (especially if a graded project was involved). Peer use was not found to increase motivation or interest in learning the content, indicators that are important not only to learning but also to recruitment and retention. The data further noted that impact/relationship of peer use without discussion of problem solving was rated as less important than instructor demonstration if accompanied by real world problem solving discussions. These findings support the importance of peer group formation and the role of discussion and collaboration as identified by Conner et.al.

*Independent/Autonomous:* Independent use of the ADB and independent opportunities *to* be involved in experiential learning were shown to influence all levels of learning. Pre-requisites of learning impacted by autonomous use included increased interest and motivation as well as increased confidence in learning the content. Immediate course specific outcomes that were reported by students and faculty include content recall of specific and general use, frequently attributed to increased graphical/pictorial visualization based on the "playing". This increased learning due to individual use was accompanied by a sense of increased self-responsibility toward learning and greater ability to transfer knowledge to new content, especially that within the immediate or next level course.

Overall, it was noted that Instructor Demonstration/Problem Solving and Independent Use were both rated equally beneficial but for different uses. Instructor Demonstration with Problem Solving increased interest, motivation for learning and helped students want to learn the material and try to solve their own problems. Autonomous or Independent use strengthened pre-existing interest and helped to develop confidence and desire for more knowledge. Use in peer settings did not rate highly in retaining and sustaining learning. This was especially true when the peer group was done in very structured settings; many students noted in these settings that the instructor or TA lacked experience and/or did relate the work to real engineering/real world problems. In these situations the students thought the peer work was “a filler exercise” and did not see any value to the work.

### *Relationship of Use with ABET Student Outcomes Indicators*

As part of the documentation of student growth directly related to professional outcomes, students involved in the experimental centric pedagogy were asked to respond to a selected series of ABET student outcomes indicators. Key findings indicated there was no relationship amongst setting and type of use and perceptions of importance of the basic ABET indicators used for this study. In addition, there was only a minimal relationship with students’ perceptions of their preparedness to practice within those domains. Of the tentative findings identified, Instructor Demonstration-Problem-solving, tended to be related to preparedness in interpreting data, designing a system component, and knowledge of contemporary issues. This finding may be a reflection of the hands-on constructivist learning that is key to experimental centric learning of key skills. Further studies are needed to track the changes in these domains and to differentiate novice, beginning, advanced and expert levels of student.

**Table 5**
**Student Outcomes by Type of Setting and Type of Use**

| | | **Type of Setting** | | | | |
|---|---|---|---|---|---|---|
| | **Perceived Changes** | **Tradit Class** | **Studio Class** | **Add on Lab** | **Integr into Lab** | **Home work** |
| ABET Indicators | Ability to apply scientific knowledge to engineering tasks | | | | | + |
| ABET Indicators | Ability to design experiments | | | | | |
| ABET Indicators | Ability to interpret data | | | | | |
| ABET Indicators | Ability to design system, component, process to meet need | | | | | |
| ABET Indicators | Ability to function effectively on multi-disciplinary team | | | | | + |
| ABET Indicators | Ability to communicate effectively as a public speaker | | | | | |
| ABET Indicators | Knowledge of contemporary issues | | | | | |

| | | **Type of Use** | | | |
|---|---|---|---|---|---|
| | | **Instr Demo Tech** | **Instr Demo Prob Solv** | **Peer** | **Indep** |
| ABET Indicators | Ability to apply scientific knowledge to engineering tasks | | | | |
| ABET Indicators | Ability to design experiments | | + | | |
| ABET Indicators | Ability to interpret data | | + | | |
| ABET Indicators | Ability to design system, component, process to meet need | | + | | |
| ABET Indicators | Ability to function effectively on multi-disciplinary team | | | | |
| ABET Indicators | Ability to communicate effectively as a public speaker | | | | + |
| ABET Indicators | Knowledge of contemporary issues | | + | | |

*+ indicates a positive low correlation; ++ a positive moderate correlation, +++ a positive high correction*

**Summary**

This paper has presented preliminary, pilot-demonstration 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 audience emphasized in the paper reflects participants in introductory, circuits, and supporting electrical engineering courses. The students reflect $1^{st}$, $2^{nd}$, and $3^{rd}$ year undergraduates enrolled in EE courses; the unique audience represents students enrolled in HBCU colleges.

*Overall Findings:* 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 pre-requisites to learning, including interest in content, motivation to learn, and confidence in ability to learn. Greater participation in hands-on, experimental learning appears to be yielding greater perceptions of knowledge gains, interest in remaining in the degree program, and ability to function as a professional engineer. In addition, during interview, an increasing number of students are expressing interest in graduate programs and research positions.

Use of the experiential approach appears to be having a slight positive impact on ABET indicators; students expressed slight changes in differences between perceptions of importance and preparation of selected skills. Faculty ratings of student ABET required indicators also supported this finding.

*Pre-requites to Learning:* Results of this study indicate that classrooms and labs that have integrated use (e.g. use of the ADB is part of the required problem solving) *and* use in homework resulted in increased confidence in ability to learn the content. In addition, instructor demonstration that reflects use in the real world and problem solving and integrated use in labs increased interest in learning more. More specifically, survey data, student interviews and responses from faculty who used integrated experimental approaches in their classes and labs accompanied by real "take-me" homework motivated current and future learning. Of these, assigned and volunteer homework had the greatest influence; if students could play, they were more inclined to learn. Similar results were noted for confidence in ability and knowledge in the content area. Use of hands-on activities was not immediately found to influence perceptions of importance in "playing" when preparing to be an engineer but the more students played as part of homework, the greater the subsequent impression.

*Immediate outcomes*: Findings indicated that the setting and type of use also influenced immediate course outcomes. The more experimental hands-on use was present in the instructional activities (instructor demo to lab to homework) the more increases were noted in a recalling AD/DC info (especially if used with homework); recalling general course content; recalling in a graphical/visual manner, having confidence in getting lab assignments done correctly, especially when used in an integrated lab, and in helping get a better grade. Faculty interviews also revealed higher level questioning both in class and in lab settings. Many noted that as students became more comfortable with experimenting, they wanted to know more about "why" things happened and less about "how" to make them happen. Students also posed more "why" questions to each other and helped each other solve immediate "how" problems. Autonomous use followed by peer groupings strengthened this relationship.

*Long-term and transferable outcomes:* Increases in ability to transfer knowledge and skills to other settings/courses/topics also were noted by both faculty and students to vary depending on how and where the student experienced involvement with the ADB. More specifically, it was noted that use in lab and homework settings helped student move course content to new areas within the course. Greater use in outside homework helped students learn to work collaboratively, even when each had their own device; use as a "comparison tool" in labs did not help to develop collaborative skills; but use as part of required homework was perceived to help develop self-direction/responsibility. Students noted that the more opportunity they had to "practice" and "play" outside of class, the more they felt they were in control of their own learning. Use in class and homework helped to develop different ways of problem solving; also, students wanted more time to "play" in class where they could ask questions of each other and of the instructor. Faculty and students both noted that this "tinkering" and "structured play" allowed them to develop stronger and more transferable skills in problem solving. Students interviewed after the end of class, who had moved on to advanced work, and faculty who taught these students noted greater ability of students to transfer the previously learned material. This transfer outside of class was aided by increased use as part of homework and more in-class but not by use in labs

*Barriers:* 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 approaches and expanded 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 course pre-requisites as well as follow up/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.

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